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SOME FEATURES OF THE STRUCTURAL DESIGN OF BUILDINGS.

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Building construction in our largest cities has for some time passed the stage at which the necessity first arose to give it the thorough technical consideration which civil engineers give to all their structural work. This observation is true both of the superstructure of the building and its foundations. It was but a short time ago, not more than fifteen or twenty years, that foundation questions in ordinary cases were of minor importance. Almost any reasonable foundation construction, which might have been designed by any intelligent mason or masonry constructor, would have been sufficient for any building located on com-

paratively firm soil or sand. It is nearly as true, but not quite, that almost any reliable building constructor could have designed the structural part of the superstructure of the building with reasonable expectation of its being safe and suitable so far as its strength was concerned for the reception of any loads which might be put into it. It is for these reasons that the present building laws of all large cities are in such an excessively unsatisfactory condition. The greater part of the ordinances now in force were designed to meet the situation as I have just described it. The structures were not more than five or six stories in height at most, and few of them were expected to carry heavy loads, while none of them were fire-proof.

All this is now radically changed. Our tallest buildings reach a height of about 400 feet above the pavement, and the occupied portions of buildings are nearly thirty stories in height. The own weight of such buildings is sufficient to impose upon the foundations loads per square foot as high as it is safe to place on foundation supports designed and built under the most competent engineering supervision. Similarly the supports of the superstructure of the building, including beams, girders and columns must be designed so as to reach the highest engineering excellence attained in the structural practice of the civil engineer. The tall office buildings of the present day, commonly known as sky-scrapers, are now carried on frameworks of steel which form a component part of the building itself. The great height to which these buildings rise make it imperative that wind loads should be considered in their design as well as those which act in a vertical direction. Concisely put, the structural design and the construction of a modern high building requires the application of the most advanced engineering principles and neither superstructure nor foundation can be satisfactorily designed or constructed except under the best engineering supervision, from the main features to the smallest details.

In considering those features of building construction to which attention will be directed, it is most suitable to begin with the foundation. It is probably not far wrong to state

broadly that the foundations of heavy buildings may be divided into three classes:

(1) Those which rest directly upon the earth or sand at the bottom of the excavation.

(2) Those which rest upon piles driven in groups under suitable portions of the structure.

(3) Those which are typified by the pneumatic caisson. That is, those in which the foundation structure is carried down to bed rock or its equivalent.

It would at sight appear that the first class is the simplest, yet many complicated questions may easily arise in connection with it. These earth foundations, as they may be called since the foundation bed is either earth or sand, must be so designed that the concentrated loads representing the supporting forces of the superstructure may be distributed from the points of concentration over such an area that the greatest allowed pressure per square foot on the earth shall not exceed a value which experience has shown to be safe either in respect to settlement or movement of the supporting material. Approximately speaking, it may be stated that the maximum working pressures allowable range from 4,000 to 8,000 pounds per square foot.

The means used for the distribution of these concentrated loads about the points of support are of considerable variety, but two methods have been largely employed. One, the older, being the inverted arch, and the other involving the use of courses of steel I-beams. The inverted arch was used for distributing the foundation pressures of the *World* Building in New York City. This building is a very high and heavy one, and its weight is carried on wrought iron columns down to masonry pedestals, which form the abutments of inverted arches of concrete. These inverted concrete arches are loaded in an upward direction by the pressure of the sand foundation bed. These arches obviously will be groined in regular or irregular series according to the location of the columns. It is a very satisfactory method of construction when the supporting earth or sand is in a suitably firm condition, and it affords an effective method of distributing the concentrated building

loads. Obviously, however, it is not adapted to the softer materials which may flow under pressures no higher than those ordinarily permitted on firm earth or sand, and, furthermore, it will not usually prove to be an economical system in cost.

Another excellent method of distributing concentrated foundation loads over a bed of sand or other firm material is instanced by the foundation of the St. Paul building in New York City, one of the more recent high buildings. In this case the bottom of the excavation is covered by a thick plate of concrete. In this plate of concrete are embedded groups of steel beams so arranged as properly to meet the imposed loads of the superstructure. These steel beams may at many points be continuous under two or more column loads, and there may be one or two or more layers of beams arranged at right angles to each other in order to distribute the imposed loads with desired uniformity. It is only necessary so to arrange the distributing beams or girders as to make it reasonably clear by calculation that the imposed loads do not exceed safe limits, as prescribed either by building ordinances or by the specifications which govern the work, such maximum limit being, perhaps, 8,000 pounds per square foot. Other methods of distribution over an earth or sand foundation bed have been used, but the two described are certainly as good as any and typify excellently this class of foundation work.

The second class of foundation supports, consisting of piles driven in the bottom of the excavation to a more or less solid stratum, has been widely employed, and has given very satisfactory results under reasonably good design and execution. Groups of piles, 2½ to 3 feet apart centers, are driven under points of column loading in such number that the load on no pile will carry more than the prescribed limit, which is 20 tons in New York City, and as much as 25 tons in some places, the assumption being made that the piles carry the entire load. It is then customary to excavate around the heads of the piles to a depth of 1 to 2 feet and fill concrete into and above the excavation to a depth of at least 1 foot over the tops of the piles. On the concrete

footing thus formed courses of steel rolled beams are placed at right angles to each other if more than one course is used. These rolled beams support the pedestal of the column above them, and they should be carefully protected by water-proof courses from any water that may find its way around the foundation. The spaces between the rolled beams and around their ends are carefully filled with hydraulic cement mortar or concrete, the beams themselves first being thoroughly painted. The groups of piles and the courses of steel beams with the concrete footing may be continuous under two or more columns. The design of these distributing beams, so as to carry their loads without subjecting them to higher fiber stresses than are prescribed, is now well known and thoroughly understood. The upward pressure on the bottom surface of each course of beams should be taken as uniformly distributed and not concentrated along opposite edges as has sometimes been done. This system of foundations, therefore, is capable of being designed with the same degree of definiteness that is required to satisfy any advanced engineering work at the present time. As a matter of fact, after the foundation is completed, the total loads are undoubtedly divided to some extent, at least, between the supporting piles and the earth or sand surrounding them and underneath the concrete. It is for this reason that comparatively high loads may safely be placed on the piles, and, furthermore, it may be stated that it is the chief reason why settlement does not take place with the miserably small piles frequently used in the foundations of buildings. These piles are often not more than 8 or 10 inches in diameter at the butt and 5 inches at the tip, with a length of anywhere from 18 to 25 or 30 feet. Twenty tons upon such a pile would make an excessive load if the pile should really carry it. The practice of using these so-called "toothpick" piles for heavy building construction is in the highest degree reprehensible and should not be permitted. The system as a system is an excellent one, but it is like any other system, in that it must not be abused if its results are to be satisfactory, and one of the most frequent and grossly inex-

cusable abuses is that resulting from using small sticks as piles which are absurdly inadequate to carry their nominal loads.

The third class of foundations cover those constructions which reach down from the pedestal of the column supporting the building to bed rock, or its equivalent. The pneumatic caisson has been more frequently used for this purpose than any other type of construction, although so-called hydraulic caissons or cylinders have been used in several instances in New York City. The pneumatic caisson consists of a box or cylinder, closed on all sides but one, the open side forming the bottom as it is used in sinking. Above this caisson is extended the vertical sides of the box or cylinder, and in the interior of this box or cylinder is carried a shaft fitted with suitable valves and other details, so as to form a closed portion called the air lock. The caisson has a roof, 7 to 8 feet above its lowest or cutting edge, forming a chamber in which men may work. The shaft just mentioned leads into this working chamber, and the air lock is placed at some point above the chamber. Compressed air from air compressors continually running, is forced into the working chamber and into the air lock at a pressure determined by the depth of excavation. This air pressure expels all water from the working chamber when the cutting edge is below water level, and enables the men to perform the operations required in sinking the caisson to any desired depth. The excavated material from the working chamber is sometimes forced out by the air pressure through small pipes, or is loaded into buckets and hoisted through the lock and shaft by the manipulations of appliances which prevent the escape of any sensible amount of compressed air. The caisson is sunk in the manner described until its lower edges reach bed rock or other hard material, the cylinder in the meantime having been loaded with pig iron or other heavy weights, which force it down against the upward pressure of the air and the friction of the material on its sides as the excavation is made in the working chamber. After the desired depth is reached, the rock is carefully cleared or cleaned of all soft material, and

the working chamber is filled with concrete by the men as they finally withdraw from it. The air lock is then removed and sometimes a portion of the shaft. The remaining portion of the shaft and the volume of the cylinder outside of it are then filled with hydraulic cement concrete to its top. If desired, a stone capping may be placed upon the cylinder to receive the pedestal under the column above it. By this means the support of the building is carried directly to bed rock or its equivalent. These caissons, either rectangular, circular or oblong in horizontal section, may be of any size, from a diameter just large enough to allow one man to work, up to dimensions large enough to receive two or more columns.

Circular cylinders have also been sunk by fitting jets or nozzles to their lower edges and forcing water through them under a comparatively high pressure. The escaping water washes away the sand and other material and allows the cylinder to sink into the annular space thus made free of sand or earth. After the cylinder has been sunk to the required depth the water is kept pumped out from its interior and the sand or earth is thus excavated in the dry. As the excavation proceeds the cylinder is braced internally, so as to prevent collapse until the bottom is reached. The bottom is then properly prepared to receive concrete, with which the interior of the cylinder is filled, the braces being removed as the concrete filling is completed.

Much has been said and written about the superiority of carrying foundation supports to bed rock. It is undoubedly satisfactory to have foundation supports carried down to rock, but it is difficult to see wherein the pile foundation fails to answer an equally satisfactory purpose when properly designed and executed. The metallic portions of pneumatic caissons and hydraulic cylinders will, within a period not by any means indefinitely long, corrode and disappear. Under proper design this is not a serious feature of the matter, but it is a feature which demands that the concrete mass shall be made as nearly monolithic as possible without unnecessary divisions by metallic plates. On the other hand, if piles are used below the water level, as they should be, they

are indestructible, and will, so far as we know, remain in place for all time. On the whole it would appear, both from rational considerations and from engineering experience to the present time, that the question of selection of either system of foundation may be based upon economical considerations only, the design and execution being assumed to be excellent in either case.

The type of superstructure, the features of which are to be considered, is that of which large buildings of the greatest heights are now constructed, and which involves a metallic framework carrying not only all the interior but the exterior walls also. This type is the latest development in the progress of building construction, although in view of the large number of buildings now constructed on its principles it can no longer be called a new type. The columns of the metallic superstructure were first made of cast iron, although at the time when this type of structure was first used by architects, civil engineers had already abandoned cast iron for long compression members and were using wrought iron columns. Practically, in the first stages of the modern metallic frame for high buildings, wrought iron columns were already in the field as compression members. These were followed by columns builts of rolled steel shapes, which now predominate in the best class of high buildings with few exceptions. In those instances in which cast iron columns have been used the prevailing sections are either rectangular or circular, although the rectangular form has been subject to a considerable number of essential variations. The sections are in the majority of cases closed, although a considerable number of columns of the I or H shape have been used. The sections of wrought iron and steel columns used in building construction are much more varied. Indeed, the number of different sections of rolled columns either of wrought iron or steel is very great, some being closed and others open. Although civil engineers have held strenuously to open columns in their bridge practice in consequence of the inaccessibility of the interior surface to the paint-brush the consensus of engineering opinion and practice has been such as to favor the use of the

closed column in building construction. There are few exceptions to that observation. Columns in a building may be and usually are well protected against atmospheric influences, a condition radically different from that in which the column finds itself in a bridge structure. It has been maintained by architects of experience that the protection surrounding many of the exterior columns of buildings is not enough to prevent access of sufficient moisture to cause serious corrosion within a limited time. It may be an open question how much moisture and even rain water may be driven through the interstices of a comparatively thin brick wall, or even a concrete wall, in which a metallic column is embedded; but it is certain that when reasonable precautions have been taken, and where reasonably good design is found, any serious corrosion has not yet been established. It does not follow from these observations that we should not attempt to increase the security of our metallic construction in buildings against atmospheric effects. Indeed, it is undoubtedly true that this feature of modern building construction does not receive sufficient attention in many buildings which are considered to be of most excellent design. I believe it can be stated with confidence, however, when the metal work of the exterior columns of a building are well painted with three coats of paint, applied to thoroughly clean surfaces, and when these columns receive such protection as it is perfectly feasible to attain in modern building construction that the question of possible corrosion with the lapse of time is one of very subordinate importance. In other words, it is believed that at the present time the exterior columns of any building may be given practically complete protection against corrosion without resorting to features of building construction which are not already found in the best of present building practice. It may be assumed therefore that the admission of closed columns in building construction is wise and justified by experience.

There are certain well-defined requisites in any good column design that have long been recognized in engineering practice. In the first place it is essential that any column should be so made that practically all internal

stresses may be eliminated, for if they exist obscure conditions arise which experience has many times shown to prejudice most seriously the resistance of the column. The cast iron column probably violates this fundamental condition in the most aggravated manner. The amount of internal stress in any cast iron column cannot bè assigned with any precision. It is only certainly known that it always exists, and that it frequently exists to a very serious extent. Columns built of rolled sections like those of wrought iron and steel, on the other hand, are practically free from internal stresses, or, at least, is is quite easy so to construct them as to reach that end, and they are usually so constructed.

Again, the metal of a column should be so distributed as to offer the greatest possible resistance to bending; or, to put this matter technically, the moment of inertia of the column section should be made as great as is feasible in those directions in which the column is likely to bend. With this judicious arrangement of metal in the cross section of the column it is imperative that its different parts shall be so secured to each other that there shall be no possibility of relative longitudinal motion; in other words, longitudinal shear must be resisted. Those parts should also be mutually supporting so that when the column fails it shall fail as a whole and not in detail. These fundamental principles are very simple in application and have long been recognized. Yet at the present time they are not always secured in some forms of columns quite frequently employed in building construction. While it is important to secure the features which have just been described in column design, it is at the same time essential that such forms of section be used as will permit of the construction of efficient details, particularly where beams and girders are attached to the columns. These details at the joints of the columns and at the points where beams and girders rest on the columns are among the most important features in the whole design of the metal frame. It is imperative, therefore, that the column section shall not only afford the desired resistance as a column, but also essential facilities for strong and rigid attach-

ments of as simple character as is feasible. It is quite within reasonable limits of good structural practice at this time to attain all these desired ends in column design without any difficulties whatever, and at a reasonable unit price for the metal work. The details of attachment should be of such character as to insure the continuity of the column at the joints and also to insure the application of the load conveyed by the beams and girders practically at the center of the column. It is an old and frequent, but inexcusable offence in design, so to detail the different parts of a metal framework as to give to the loads an eccentric application to the column. In no practical case is it possible accurately to measure the eccentricity of an applied load. The result is a bending stress of unknown amount inadequately provided for, and which is added to the direct load of compression properly resting upon the column. It is essential to good design, therefore, that all eccentric application of wall or floor loads to columns be avoided, as is done in the best of building construction at the present time. That is, such results are reached in columns of structural steel, but they are not reached in the case of cast iron columns for the simple reason that it is practically impossible to do so. I say it is practically impossible to do so for the reason that too much labor and too much complication of detail is requisite in order to attain such ends. As a consequence, loads are almost invariably applied to cast iron columns on lugs or cantilever projections, the bearing surfaces of which are in the rough, precisely as they come from the sand. These details are invariably ill-fitting and crude in every respect so that the applied loads are just as likely to rest on the edge of the projection as anywhere else, and, in fact, a good deal more so. A few critical examinations only of the joints and lugs of cast iron columns, carrying loads, will satisfy almost any competent mind not already biased in favor of the cast iron column as to this point. These features of cast iron column practice are all the more inexcusable for the reason that it is the poorest of all structural metals to resist bending and tension. Indeed, it is structurally unpardonable to permit cast iron to be used in tension at all.

Whenever a cast iron column receives an eccentric load, and, unfortunately, it seldom receives any other, a considerable bending immediately takes place, and to such an extent that it is practically certain in many cases that one side of the column is subjected to tension.

It has been thought and maintained by many advocates of cast iron columns that they are more economical than either wrought iron or steel, although at the present time the question is one of cast iron against structural steel alone. As a matter of fact until within the past year, the computation of the carrying power of cast iron columns, as they are used in buildings, has been a matter largely of guesswork. Formulæ based upon the toy cast iron pieces, used by Hodgkinson in his historic tests fifty years ago, have been constantly employed in building practice. In 1889 a series of tests of full-sized columns was made in the large Emery machine at the U. S. Arsenal at Watertown, Mass., but the series was not sufficiently extended to make the results a basis for new formulæ. In 1896 and 1897, however, other tests, executed under the auspices of the Department of Buildings of New York City, were made in the 1,000-ton testing machine of the Phœnix Iron Company, at Phœnixville, Pa. The results of these tests and those made at Watertown, Mass., afford complete data for satisfactory formulæ for the resisting capacity of cast iron columns, although a considerable portion of them are more or less erratic. Those erratic results will not surprise any engineer who has had much experience with cast iron compression members. The failures of the columns usually took place at some point of defect. The columns were all circular in section and hollow, with thicknesses and general dimensions about as found in ordinary cast iron column practice. As in all such members, however, the thickness frequently varied considerably from one side of the column to the other, and gave rise to consequent weakness. Again, the records of the tests showed frequently such defects as "foundry dirt," or "honeycomb between inner and outer surfaces," "bad spots," "cinder pockets and blowholes," "flaws and foundry dirt," and so on to the end of the list. In other words, adven-

titious defects often determine failure and prevent carrying the load which sound metal and the desired distribution of it would enable the column to carry. As a result of these tests it is found that the ordinary cast iron column formulæ, which have generally been used in practice, credit the columns with just about twice as much load as they are able to carry for such lengths as are frequently used. Taking the entire range of lengths of columns permitted in ordinary practice, the formulæ commonly used make cast iron columns from once and a half to twice as strong as they actually are. That is, the safety factor is actually but one-half to two-thirds of its nominal value. If the results of these full-size cast iron column tests are plotted so as to be shown graphically the results which I have just described appear very evident. Such a graphical representation will also show that if the same degree of safety is secured by the use of cast iron columns as is reached in the use of structural steel columns, the cross-sectional area of the cast iron columns would have to be about twice that of the steel columns. Under such circumstances it is quite evident that the supposed economy of the cast metal would disappear. In fact, it may safely be asserted that if the same degree of safety is secured, the structural steel column will be the cheapest, as it is in all respects the best.

Although many high buildings are now erected alongside of or between other buildings for at least a part of their heights, and to that extent are protected from winds, yet wind bracing or substantial wind portals are an essential feature of every good steel frame design, nothwithstanding the fact that they are generally omitted. There are always times when tall buildings are subject to the action of high wind pressure. If they are then in course of erection the bracing or portals are necessary for safety, and they give the building desirable stiffness after completion. The frames of many tall buildings have been run up ahead of walls and partitions, carrying a considerable number of tile floors and tiers of columns absolutely unbraced laterally. It is amazing that a wind disaster has not overtaken a number of such cases. One or two at least have been

blown so far out of plumb, that they have with difficulty been saved and brought back into position. Either bracing or portals can always be used; they cost little, and make the difference between certain stability in all conditions and possible failure in at least some.

[*To be concluded.*]

Special Meeting, March 23, 1898.

BUILDING-STONES—ELEMENTS OF STRENGTH IN THEIR CONSTITUTION AND STRUCTURE.*

By Alexis A. Julien,
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(*Concluded from p. 397.*)

IV. RIGIDITY.

This property, in contradiction to the popular view, far from being characteristic of stone, is rather one of those to be specially sought after in a variety chosen for building purposes. A most desirable element of strength lies in internal immobility of grains or lack of plasticity; since any internal motion or change of relationship among these is likely to disturb the completeness of original interlockment, cementation and absence of strain, and to result in permanent disruption. There are three causes of such plasticity to be guarded against, within a stone subjected to great pressure: Cleavage and gliding-planes, sliding-surfaces, and the enclosure of lubricants.

(1) *Cleavage and Gliding-Planes in the Mineral-Grains.*—All the easily cleavable and frequently twinned minerals

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* Abstract published in *Stone*, 1898, and elsewhere. Reference has been made in the notes to the more important statements which have appeared in the literature of the subject, during the year since the reading of this paper, concerning points discussed herein.

—such as the feldspars, hornblende, calcite, dolomite, etc. —from this point of view, are possible sources of weakness in proportion to their abundance in any stone and to the readiness of their cleavage, distinctly shown in a dolomite-marble like that of Tuckahoe, N. Y. (*Fig. 17*). Especially in coarse marbles like this, the twinning or "gliding-planes" of calcite and dolomite mark the results of stress from ancient shearing, and are equal sources of dangerous motion under pressure; so, also, in the granites, with the twinning-which are the equivalent of the gliding-planes, in the triclinic feldspars.*

Were it not for the property of surface-adhesion in subsequent action, where this may be favored by the conditions, the plasticity and flexibility of marble would have found inevitable consequences, apparently, in rapid or immediate disintegration. Of that result we have evidence where surface-adhesion has been counteracted by weathering and infiltration, in the observed deep decay of granites, dolomites, marbles, etc., into loose sand. In the crushing of a non-homogeneous rock, such as granite, during subterranean movements, intermixture of fine particles or dust of a brittle mineral, like quartz, seems often to have interfered with continued cohesion of cleavage-planes of the other constituents, and so to have precipitated disintegration of the mass.

It has often been pointed out that the minerals of all others of the most facile cleavability, the micas, and especially the films of the soft and pliant hydromicas, whose

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*This is well illustrated in a description recently recorded in Maryland: "The rock from Texas is a very coarsely crystalline marble or 'alum stone,' in which the individual grains are sometimes ½ or ¼ of an inch in diameter. The constituents are weak in themselves, and they are weakly held together. The single grains show twinning striæ parallel to the crystal — ½ R that have been produced by a pressure, causing a gliding of the molecules over one another which has weakened the strength of the grain. Such a texture as is here shown renders the rock nearly worthless as a building-stone where small blocks must be used and great weights sustained. This is emphasized by the determination of the crushing strength, which is very low."—*E. B. Mathews, op. cit.*, 177.

flakes in some stones lie in parallel arrangement,* and in others irregularly disposed in all positions, appear to have been best adapted to promote internal motion and yielding of the grains of a stone under compression, in the same way as they act in quicksands. From their fissile texture, they have easily loosened into polished scales, which must have served under pressure as true a lubricant for motion of the surrounding grains as the scales of graphite on the pinions of an engine. In some rocks of slaty structure, "the laminæ are thrown into a series of small contortions in such a manner that the flakes of mica lie chiefly along certain definite parallel planes oblique to the general direction of stratification, which thus become planes of easy fracture or cleavage,"† and also, I think, of possible yielding and motion under heavy load, where, as in some parts of Europe, such rocks are used as building-stones. Probably the least objectionable form of mica, as affecting the rigidity and compressive strength of a stone, is that of shreds, strings and irregularly crumpled scales.

(2) *Sliding-surfaces* in rock structure. This term I would apply to the innumerable open fissures and clefts, often with smooth or even polished walls, which occur not only within but between the grains of stone, and which are found distributed through all rocks which have been subjected to great pressures during earth movements. Along the axial lines of folding and crumpling of strata, geologist, miner and quarryman constantly meet on joint, fissure, fault, schist and bedding-planes, with the common and often beautiful display of *slickensides*. This old mining term is used to describe the highly polished and striated sheets and bosses where the jaws of the rock once ground together and oppos-

* "It readily decomposes, and is an element of weakness, not alone from its disintegration, but likewise from the tendency of the flakes to lie all the same way and make planes of easy cleavage, along which the stone flakes and scales on exposure. The scaling is much worse where the mica is much decayed. It is one of the most injurious minerals that occur in sandstones."—Hopkins, *op. cit.*, 16.

† A. Harker, "On Slaty Cleavage and Allied Rock Structures," Rep. Brit. Ass. Adv. Sci. (1885), 837.

ing walls and seams rubbed and slipped over each other. Where the yielding was intermittent and the motion by jerks and starts, numerous miniature faults were produced throughout the mass, often shown by the faulted veinlets of calcite, invisible to the unassisted eye, in a thin section of limestone, though these may elsewhere be distinctly seen in a mere pebble picked up from the beach. Good illustrations of the larger forms of these have been thus described: "The polishing effects of the readjustments between the beds may often be seen in the slickensided surfaces of the major and stronger beds, and in cases of implicated folding the same phenomena are observable between the thinnest laminæ. A most striking instance of this polishing is seen in the Jura Mountains, where, at many places, both sides of the strong, thick layers of Jurassic limestone are polished as smoothly as if glaciated. They reflect the sun like an imperfect mirror. At some places where the folds are steep, layers have fallen down along these movement planes, exposing great surfaces of beautifully polished rock. In the folded Cambrian quartzites of Doe River, Tenn., the polishing of the layers by accommodation is scarcely less strikingly illustrated."*

But the view I now wish to press is that these well known macroscopic forms, familiar to the field geologist, must represent to but a small degree the enormous distribution of microscopic polished surfaces, plane, curved and irregular, intervening between the clefts and around the very grains in the interstices of stone. These interstitial slickensides may be assumed to abound especially in material in which the microscope reveals the presence of clefts and faults, and of grains (autoclastic) more or less rounded by mutual attrition during flowage, under compression. Microscopic faults, like those often shown in thin sections, presumably with slickensided surfaces, traverse the entire mass of many kinds of stone in the most complicated network, and have been connected with the development of joint-planes.† To

* Van Hise, "Principles," etc., 600.

† "The study of many thousand divisional planes, which would certainly be regarded as joints by almost every geologist, has led me to the conclusion that

one class of these minute dislocations Professor Heim* refers as fold-faults (falten-verwerfungen), in his discussion of his first type of cleavage, *strain-slip cleavage* (ausweichungsclivage), "that produced by a succession of displacements or minute faults, resulting from small contortions." As these polished surfaces usually lie in a multitude of planes variously inclined, the cohesion of many must be easily overcome by pressure in definite directions. Their consequent yielding and slipping must sometimes develop a grave source of weakness in building-stone; the resultant internal gliding, therefore, concerns the architect, engineer and builder as seriously, as it interests the geologist in studying the motion of strata, or the miner in searching for a lost lode. These glistening planes are familiar to every observer on the seams or folia of shales, slates and schists, where even the dissemination of sericite or other mica is commonly a proof and result of the sliding under compression. But the objection that the detection of the sheen on these minute surfaces must probably always remain beyond the reach of microscopical observation,† and that the above considerations are, therefore, in part presumptive, will hardly justify any further neglect of tests and precautions yet needed to guard against the danger of this concealed characteristic of the structure of stone. However, it must be

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the jointing and the faulting are concomitant. The faults are often extremely small, but it is very rarely that in a system of joint planes throws of an eighth of an inch or less cannot be detected; and where the rock is hard, slickensided surfaces will be found, even when the relative movement is much less than an eighth of an inch. Few geologists have been in the habit of looking for faults of such tiny dimensions, and I believe that the distinction between faults and joints has arisen from this omission. Partings due to tension would be free from slickensides."—G. F. Becker, *Bull. Geol. Soc. Am.*, IV (1893), 73.

* "Untersuchungen ueber den Mechanismus der Gebirgsbildung," Basel, (1878), II, 49–58.

† "The development of minerals along the crush-planes only takes place on an important scale in rocks originally crystalline, and even there, although the general effect is plain, the individual mineral constituents by which it is produced are for the most part extremely minute. It is a remarkable fact that, in a certain sense, a sheen surface is often more conspicuous to the naked eye than it is under the microscope."—T. G. Bonney, *Quart. Jour. Geol. Soc.* (1886), Proc., 107.

admitted, that, under those conditions in the subterranean metamorphism of rocks which have resulted in the closing of interstitial cavities (at a depth of 10,500 to 12,000 meters, according to Hoskins and Van Hise), the polished faces of these minute dislocations have become united and welded by molecular cohesion, in part or altogether, and their influence obliterated to that degree as surfaces of motion and weakness in the stone.

(3) *Lubricant.*—A strange disregard has hitherto prevailed, in my opinion, as to the influence of water on the internal mobility of stone. In the usual tests of the architect and engineer on compressive strength, the cubes used for the purpose have been scrupulously provided in a carefully air-dried state; apparently with the assumption that moistening or saturation would exert about the same effect upon the compressive resistance of stones of every kind. Yet, it is well known, the absorption-coefficient varies very widely, from a minimum in the dense stones, such as fine granites, up to that of porous cellular stones which absorb water like sponges, such as the poorer varieties of sandstones and limestones of loose texture.

Another needful coefficient, rarely distinguished, we may call that of absorption of moisture, the *moisture-coefficient*,* in distinction from that of saturation with water. The one indicates, as already suggested, the capacity of the seams and clefts, and merely the walls of the pores, to condense and hold watery vapor from an atmosphere saturated with moisture; the other, the *saturation-coefficient*, pertains to the entire capacity of the pores when filled with water; both are combined in the ordinary *absorption-coefficient*, in other words, the capacity, for saturation with water, of the entire interstices (the distinction of coefficients made elsewhere by me, in a study of the Syene granite,† referred merely to two methods and degrees of saturation of the pores). The moisture-coefficient differs widely, too, though not to the same extent as that of saturation, in the different kinds of stone.

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* N. H. Winchell, *op. cit.*, 185–186.

† "A Study of the N. Y. Obelisk," 158–161.

A familiar fact in common experience has been the decided softening and weakening of stone, under pressure, attrition or blows, while thoroughly soaked with water. It should be remembered that such softening may prevail continuously in a stone, even to the excessive degree produced by saturation, *e. g.*, from climate, as during a rainy season; from low or buried position, in foundations below the ground or the water-level; or even from permanent submersion beneath fresh or salt water, as in the foundations of a bridge, dock or pier. Notwithstanding these well known facts, few results of compression-tests have yet been recorded on cubes of stone, while in saturated condition by fresh or by salt water. But this universal constituent of stone, in the form of moisture, and common one, in the form of interstitial filling, in positions of saturation, serves in all cases, in proportion to its amount, as a lubricant of the other grains, promoting their motion and yielding under pressure and consequent weakening of the whole stone. One might as reasonably reject from consideration the micas in a granite or marble, as this permanent constituent of every stone, and always active lubricant, water.

We need to go back nearly a quarter of a century for the record of the few but most important experiments on this subject (*Revue de Geologie*, XIV, 1875–86), viz.:

CRUSHING WEIGHT (IN KILOGRAMS).

Kind of Rock.	Locality.	Size of Cube in C. Cm.	Wet.		Air-dried.		Stove-dried.		Authority.
			Range.	Average.	Range.	Average.	Range.	Average.	
Chalk	—	30	13·9–16	18·6	16·5–35	23·5	80–92·5	86·2	Tournaire and Michelot.
Chalk	Issy.	5	—	12·9	—	23·6	—	36·4	Delesse.
Limestone (Calcaire grossier)	Vitry.	5	—	26·9	—	52·8	—	76·	"
Limestone (Calcaire grossier)	St. Denis.	5	—	21·8	—	31·2	—	48·7	"

The percentage losses of compressive resistance in the above four kinds of limestone, comparing the air-dried with the saturated cubes, are respectively: 20·85, 45·34, 49·05 and 30·13 per cent. A few more recent experiments have been published by F. Soule* (tabulated below), on two kinds of building-stone, from Calaveras County, Cal., in air-dried cubes, and in cubes saturated with water during seven or eight days. The influence of saturation of stone on its compressive resistance seems to rapidly increase in degree with the amount of absorption.

COMPRESSIVE RESISTANCE.
(In pounds, to the square inch.)

Building-Stone.	Locality.	Total Absorption (p. c. of weight.)	No. of Cubes.	Dry.	No. of Cubes.	Saturated.	Loss (per cent.)
Marble . . .	San Andreas, Cal.	0·30	4	3880	1	3730	3·87
Volcanic tufa	Santa Maria, Cal.	22·53	2	5435	2	2765	49·13

For the foundations of the New York and Brooklyn Bridge, the dense limestones from Kingston and Roundout, Catskill and Lake Champlain, were used, on account of the cheapness of the stone, its high specific gravity (2·69 to 2·75), and great crushing resistance (13,750 to 25,000 pounds to the square inch), the last property determined in the usual way on cubes of the stone in carefully air-dried condition. But who can now tell us the present crushing resistance of the blocks in that foundation, after their submersion in salt water for twenty years? Or that of more porous and absorbent stone, such as gneiss (*Fig. 7*), generally used throughout New York and Philadelphia in foundations of heavy buildings, of bridge-piers, etc., on the strength of results obtained on air-dried cubes? Or even that of the soft, porous and highly absorbent varieties of the imported "Carlisle stone," the freestones from Ballochmile, Gatelawbridge and Corsehill, Scotland (*Fig. 18*), in masonry com-

**Stone*, XVI (1898), 433-434. Similar results, but with smaller differences, were obtained by Dr. Böhme, on testing sixty-four samples of limestone and fourteen of sandstone, in wet and dry cubes.—"The Strength of Quarry Stones," Am. Arch. (1882), 220.

monly seen in our streets, in contact with the soil, and so kept in permanently damp condition?

Again, petroleum and bitumen are frequent constituents, to a small extent, in sandstones and limestones, some of which have been brought into use as building-stones, such as certain sandstones of Ohio and limestones of Indiana with oily exudations. These also must act as lubricants of mineral-grains, but have been left out of consideration, in regard to their influence toward the strength of stone, in rejection of infiltrating water, or toward its weakness, in diminution of rigidity.

Besides the mica-plates, to whose influence as lubricants reference has already been made, graphite itself is commonly distributed in soft greasy flakes throughout limestones, gneisses and schists in Canada, on the southern border of the Adirondacks and elsewhere. Its presence would decidedly favor the internal flow of rock-grains under pressure, though such materials have as yet been rarely used in building. However, Vogt refers to its decided weakening influence on the compactness of certain marbles of Norway.

The general occurrence of such indications of weakness and yielding—cleavage, gliding-planes, sliding surfaces, and the presence of liquid lubricants—testifies to the conditions of instability and mobility which prevail in the structure of all building-stones.

Reference has already been made to anomalies constantly observed in the behavior, under stress, of stones of supposed uniformity in structure and homogeneity. Such have been, for example, remarkably abundant and strange during the usual crushing-trials of stone-cubes, even on those cut from the same block, of seemingly compact material, and carefully tested under the same conditions. In one, it may be at a low pressure, a crack suddenly appears, and the cube falls apart. Another becomes seamed by many fissures and splits into irregular fibers, flakes or lumps. Another explodes into gravel and powder, surrounding rudely pyramidal or conical forms. In another, the tensions seem to be more equably distributed, like those of the unstable molecules in unannealed glass, a

Prince Rupert drop, of which if you break but the tip, the whole bulb vanishes to powder. In such a cube, after long waiting, there comes at last a sudden report, and the mass of powerful stone shrinks in an instant to a handful of dust. This seems to be the ideal uniformity of internal conditions desirable within a stone, which thus ultimately meets the instantaneous fate which befell the far-famed "one-horse shay."

Yet from the four figures in this supposed experiment for resistance to compression, varying perhaps to *thousands of pounds*, obtained on these cubes (the differences on 2-inch cubes of the same stone, tested between wooden cushion-blocks, in Gillmore's experiments,* ranged from 6,000 to 15,000 pounds!), the average is ordinarily taken for the business report, and forms the basis, to the architect or engineer, for his "safety allowance," while the significance of the variations is disregarded and lost. There is evidently imperative need in such work of preliminary microscopical examinations of the internal structure of stone, and of chemical and physical tests of a special class, to thoroughly investigate the local minute tensions already existing and the defects of rigidity tending to flowage—those internal imperfections hitherto vaguely termed "flaws," "checks," "sand-cracks," etc., by experimenters—and to measure, if it be possible, the power of resistance of the stone to these; or, in other words, its coefficient of stability.

In this partial review of the characteristics of stone, with regard to mineral constitution and structure, in adaptation to its use as a building material, I have tried to call special attention to features whose importance appears partly neglected or entirely ignored. On their proper recognition, by exact methods of trial, must be founded the final selection of true and systematic methods for the series of tests for the correct treatment of different varieties of stone and for the best processes for its protection and preservation in our trying climate.

* Gillmore, *ob. cit.*, pp. 28–31.

We may safely fancy that in the kingdom of Assyria, 6,000 years ago, the long-bearded architects of Asshur-banipal, as they stood planning the proper dimensions of alabaster-slabs for the wainscot in the palace at Koyunjik, relied largely on the Royal Rule of Thumb. This venerable rule is still extant, and bars the way to progress. An undue dependence upon so-called practical experience, with its limited glimpse of the internal nature of stone—a material whose most important structural characteristics are far beyond the reach of the unaided human eye—or, on the other hand, upon the present chaos of scientific methods and results of trial, unsystematic and uncorrelated, must inevitably prolong and increase the substitution of ashlar in thin veneering, of the petty mosaic of brick, of flimsy iron skeletons, and of pie-crust terra-cotta, in place of solid stone. But undoubtedly difficult as may be the thorough comprehension of the complicated structure and characteristics of this material and its skilful adaptation to present needs, these are well within the resources of modern investigation.

DISCUSSION.

T. C. HOPKINS, State College, Pa.:—Permit me first to express my pleasure and satisfaction in listening to Dr. Julien's remarks, which were certainly instructive and interesting to any one who has attempted to solve any of the many intricate and difficult problems connected with the durability of rocks, particularly in reference to those used for building purposes.

One of the important phases of this problem that needs further investigation is the action or influence of the quarry sap or quarry water. Its importance is realized by every intelligent quarryman, but a satisfactory explanation has not yet been given. It is a matter of surprise that the stone which comes from the quarry soft and friable, so soft at times that small pieces may be crushed to grains in the naked hand, should, after exposure for a few weeks, months or years, become so hard as to strike fire under the hammer; so hard, often, as to make it exceedingly difficult for the stonecutter to dress it to the desired form.

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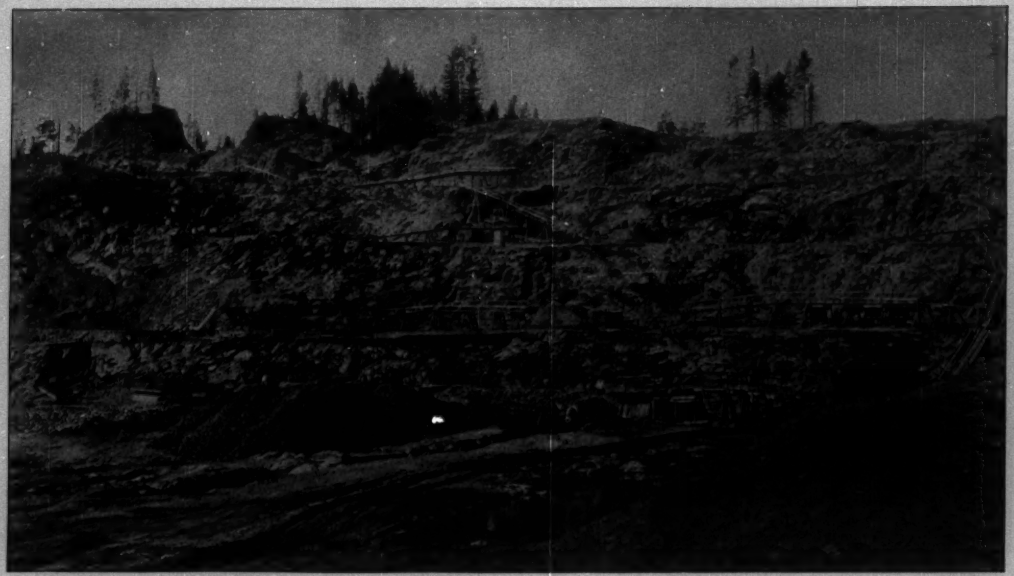

FIG. 2.—Workings of the Blagodat mines.

FIG. 3.—Workings of the Blagodat mines.

(Nitze)

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What causes this great change? The quarryman says the sun burns it hard, and he may not be far from right. What we want to know is the chemical or physical changes which take place in the stone. It must be more than the simple evaporation of water, and yet it seems hardly probable that it could be entirely from material held in chemical solution in the water. Is it not possible that sunlight and the atmosphere are more active on the commonly considered insoluble materials (such as quartz) than we think? How much of this indurating (might it not even be called metamorphic?) action is due to the physical or chemical action of the sunlight or how much to simple desiccation is a problem for investigation.

Another question of scientific interest is the source of the carbonic acid found so abundantly in the quartz of the granites. Is it all of organic origin? Can we consider it proof that the rock was formed from sediments from the lime and other carbonates or from organic material, or is carbonic acid a constituent of the original or first-formed igneous rocks?

Later, in reply to Dr. Day's remarks, Mr. Hopkins said that he thought that the hydrochloric acid test on granite would be of very little if any value in determining the comparative durability, as durability depends not on solubility in acids alone. It introduces an artificial condition to which the stone may never be subjected in nature, and while it will give the relative powers of the specimens to resist acid solutions, this may or may not be the ratio in which they will resist the atmosphere. It might even be an inverse ratio.

What would be more satisfactory, although more expensive would be to test the stones in the atmosphere itself. The results would not be immediately available, but it would be only a comparatively few years until useful results would be apparent, and in the course of time architects, builders and others would have data concerning our building-stone that would be invaluable; results that would also be of great value to scientists and serve as a check on any laboratory tests that might be used. Tests of this charac-

ter would be properly in the line of government work, not only on account of its expense, but on account of its long continuance, the impersonality of the results, and the better facilities both for performing the tests and distributing the results.

Stated Meeting, March 9, 1890.

THE IRON ORES OF THE OURAL MOUNTAINS, RUSSIA.

BY H. B. C. NITZE.

At a time when the Russian Government is assuming a more liberal and progressive policy for the development of its home industries, and is giving encouragement to the investment of foreign capital, it may be of interest to say something of the iron-ore resources of this rich and vast territory.

I shall confine my remarks to the Oural Mountain region, the cradle of the Russian iron industry, which was founded by Peter the Great over two centuries ago. The growth of this industry has been extremely slow, owing chiefly to the great inaccessibility of the region; and for this reason, too, the mining and metallurgical methods have progressed but little towards the present high state of modern practice.

But, with the extension of various important railroad connections, at present either completed, in course of construction, or definitely proposed, a progressive development of the Oural iron industry may confidently be expected.

The region under consideration may be divided into the northern, central and southern Ourals.

The northern Oural district is the least developed. Some small deposits on the western slopes produce 45 to 50 per cent. ores. Further in the interior of the mountain chain are large ore-bodies, such as the Kutinski and the Jubrischski mines, which produce rich specular ores, containing 60 to 65 per cent. metallic iron, at a cost of 65 cents a ton, at

the mines. The district of Bogoslovsk produces 50 to 60 per cent. ores, worth 90 cents at the mines.

The ore-deposits of the middle or central Ourals are more developed, and are concentrated within a smaller area. The two principal producers are the Blagodat mines at Kouchwa, and the Wyssokaja mines at Tagil, both on the line of the Perm-Ekatherineburg railroad.

The Blagodat mines, property of the Crown, are situated on the western slope of Mount Blagodat, an isolated peak, which rises to a height of about 500 feet above the surrounding country, and 1,150 feet above the sea-level. The summit of this mountain is occupied by a Greek chapel, erected as a monument to Stepan Tchoumpin, who, according to tradition, was the discoverer of the ore-deposits.

The predominating rocks are porphyries, which show all phases of transition, from coarse-grained augitic syenites to perfectly compact orthoclase rocks. They lie in contact with Devonian strata which have been largely altered to garnet-epidote rocks, the result of contact metamorphism. The ore is magnetite. Attention is directed to the structure of the ore-deposits and the enclosing rocks (see *Fig. 1*). There is a more or less distinct arrangement in parallel beds, folded into an anticlinal or saddle near the crest of the mountain, one member dipping westward with the slope of the mountain at an angle of 40° to 40°. The regularity of this structure is affected by two series of faults, the one extending north and south, and the other nearly east and west. Owing to the throws of these faults the original position of the beds is often considerably disturbed. The ore-bodies contain some feldspar, and at the boundaries of the beds they pass gradually into the composition of the porphyry. They may be looked upon as magmatic differentiations in the porphyry mass. The mines are in the shape of immense, terraced open cuts (see *Figs. 2* and *3*).

The ores average 60 to 65 per cent. metallic iron, and are very free from deleterious ingredients. The cost of the ore at the mines is $1.27 per metric ton. The annual output is about 7,000 metric tons, consumed exclusively by the government iron works.

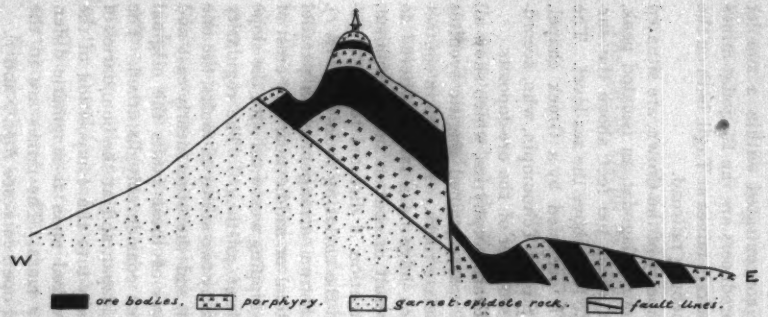

FIG 1.—Showing relation of ore bodies and country rock at the Blagodat mines.

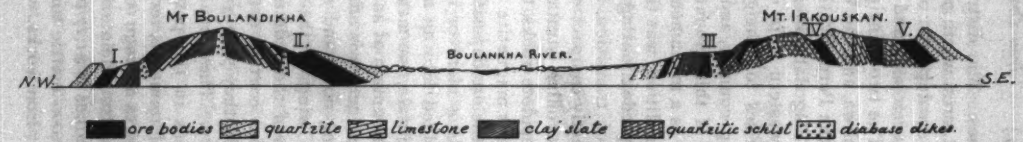

FIG. 5.—Geological section at the Bakalski mines.

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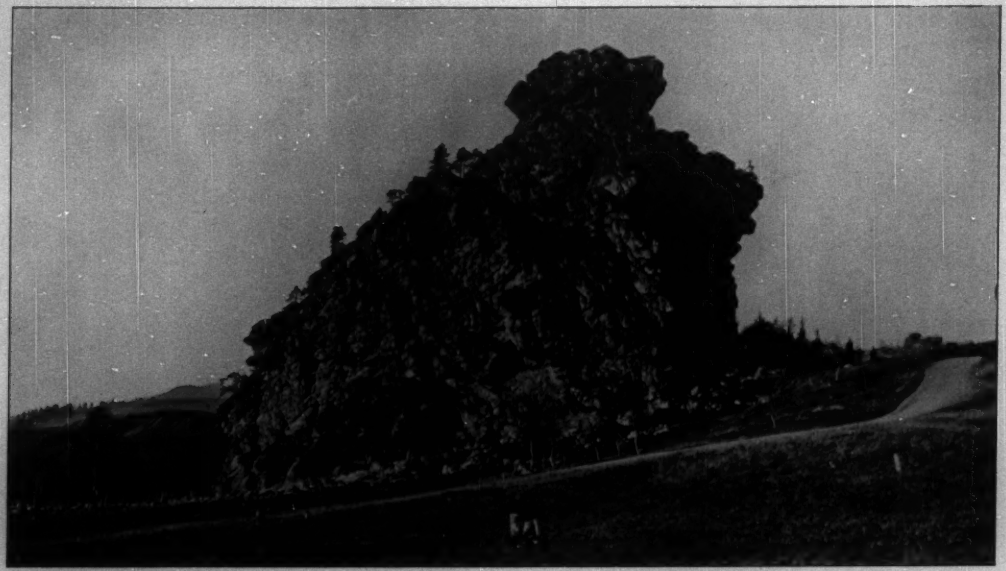
FIG. 4.—Workings of the Wyssokaja mines at Tagil.



(Nilze)

FIG. 6.—Quartzite outcrop at the Bakalski mines.

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The Wyssokaja mines are situated on Mount Wyssokaja (High Mountain), at Nijne-Tagil, about 30 miles south of Kouchwa. They are the property of the heirs of P. Demidow, prince of San Donato. The character and structure of the ore-deposits and associated rocks, as well as other conditions, are in all respects similar to those of Blagodat. *Fig. 4* shows a view of a part of the Wyssokaja mines. The annual output is 20,000 metric tons, which supplies the neighboring iron works of Nijne-Tagil, Niewiansk, Alapaievsk, Werkhissetsk, Soukhsounsk and Revdinsk.

The southern Ourals are the richest in ores. The two principal localities are the Bakalski mines, in the district of Slatoust, and the Magnetnaia mines, in the region of the Oural Cossacks.

The Bakalski mines are situated at the terminus of a branch railroad, completed during the summer of 1898, from the station Berdiansk on the Trans-Siberian railroad. The country is traversed by three principal ore-bearing mountain ranges, the Chouida, the Irkouskan and the Boulandikha, which are composed of Lower Devonian strata in the following order of geological succession (see *Fig. 5*):

(*a*) Quartzites and sandstones, constituting the crests, and standing out in fantastic relief (see *Fig. 6*).

(*b*) Diversely colored schists enclosing subordinate beds of gray dolomitic limestone.

(*c*) Quartzitic, sericitic and argillaceous schists, with black and gray dolomites.

These rocks are intersected by highly altered diabase in the form of intrusive dikes, bosses and sheets. The ore-bodies (limonite and spathic ore) occur as beds, reaching a thickness of as much as 130 feet, in the horizon (*b*), and are intimately related to the dolomitic limestones, the gradual transition of limestone to spathic ore and limonite being clearly visible. The anticlinal structure, particularly of Mt. Irkouskan, is broken by a series of faults, extending in a northeast and southwest direction with the course of the mountains.

The mines of the district fall under three ownerships:

(1) those operated by the Crown, supplying the Satkinsk and Slatoust works; (2) those operated by Mr. Balachew, supplying the Simsk and Nikolaiewsk works; and (3) those operated by Prince Bieloselsky-Bielosersky, supplying the Kataw and Jourezan works. The total annual output of these mines is 100,000 metric tons of ore, containing up to 60 per cent. metallic iron. The cost of mining, which is carried on entirely in open-cuts, is 58 to 66 cents per ton.

The Magnetnaia mine is situated on a mountain of the same name on the left bank of the Oural River in the country of the Cossack steppes. It is leased by the Bieloretzki iron works, and has an annual output of 50,000 metric tons of high-grade magnetite ore, costing something like 50 cents per ton at the mine.

There are a number of smaller mines in the southern Ourals, furnishing a total annual output of about 100,000 metric tons. Among these are the Awzianski and the Inersk mines, producing 50 to 60 per cent. ores at a cost of 72 cents per ton.

The total production of pig-iron in European and Asiatic Russia for the year 1897 was 1,835,540 metric tons, of which 723,500 tons were from South Russia and 676,000 tons from the Oural region.

Some few of the Oural mines are fitted with modern mechanical appliances, as the Auerbach mine in the Bogoslovsk district, but the vast majority are operated entirely by hand labor and horse-power, in the most primitive manner. When not occupied in the field, the peasant works in the mine, usually on the tribute system. This class of labor is cheap, but uncertain, and the work is spasmodic and ruinous to the future development of the mines. The hauling is usually done by women and children in veritable toy carts holding about 500 pounds. The blast furnaces are of antiquated types, having a capacity usually of not over 30 to 50 tons. The fuel is, without exception, charcoal.

The evident lack of progress in the development of the iron mining and metallurgical industry must be attributed largely to the dearth of transportation facilities. The iron ores of the Ourals are of excellent quality, and the resources

are abundant. It will be necessary, among other things, to connect these ore supplies with the Donetz coal basin of South Russia, and steps in this direction have already been crowned with partial success.

A STUDY OF THE MICRO-STRUCTURE OF BRONZES.

By E. Heyn,

Engineer in Charge of the Micro-Metallurgical Department of the Royal Prussian Testing Bureau at Charlottenburg. Translated for the *Journal* by Paul Kreuzpointner, Testing Department Pennsylvania Railroad, Altoona, Pa. To which are appended remarks by the Translator, A. E. Outerbridge, Jr., and Albert Sauveur.

Mr. Heyn:—In Vol. CXLVII, No. 1, of the *Journal of the Franklin Institute*, a very stimulating lecture is published on the micro-structure of bronzes.

The lecture was delivered by Mr. Outerbridge. The address, as well as the discussion following, are proof of a very lively interest on the subject of metallography by prominent American specialists.

However, it is our experience that frequently the original enthusiasm with which a subject was taken up meets with the discouragement of real or imaginary disappointments while pursuing the subject under investigation. Such a reaction is dangerous to the cause, having a tendency to prevent progress or at least make progress more difficult.

Mr. Clamer summarized the points of the lecture and discussion in the following sentences:

"Structure is not only affected by the temperature of pouring, rate of cooling, or, in other words, heat treatment, but also by the size of casting and method and time of etching, etc., and for this reason I agree with Mr. Outerbridge in his statements regarding the necessity of standard methods."

In the foregoing, I wish to lay particular stress on the point where Mr. Clamer says: "Structure is affected by method and time of etching," because this point is the one

where, under unfavorable circumstances, the above-mentioned reaction may be produced. To prevent this is my desire.

The micro-structure of a metal, in whatever condition of temperature or mechanical treatment is peculiar to that condition, and remains unalterably at that condition precisely as the other properties of a metal, like strength, hardness, specific weight, etc., are peculiar to a given temperature or stage of mechanical treatment of a metal.

Hence, it is impossible to conceive the micro-structure itself to be changed by the time of etching.

Recognizing this as the foundation upon which to build all metallographic work, I am in entire accord with the views of most metallographists, particularly with those of my teacher in this line of work, Prof. A. Martens, who most kindly permitted me to assist him in the continuation of his work.

It is true that, under certain circumstances, we may receive a varying impression of the micro-structure according to the manner and form such micro-structure is presented to our vision. According to one method we make the structure visible by showing the difference in hardness by means of the so-called "relief-polishing." According to other methods we try to obtain a knowledge of the differences in structure by the peculiarity of different portions of a specimen which have been colored differently by an etching fluid; or we make use of the fact that some portions of a structure are attacked more readily by a given acid than others. One and the same part of a structure may assume a different color according to the kind of etching fluid used.

However, all the various impressions, produced by various means must lead us, with due regard to all accompanying circumstances, to a proper observation of the characteristics peculiar to a given micro-structure. Using different means, the observer is able to acquire a knowledge of the various properties peculiar to the different elements of which the structure of a metal is composed, thus enabling him to get a general view of the micro-structure as a whole.

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Fig. 1.

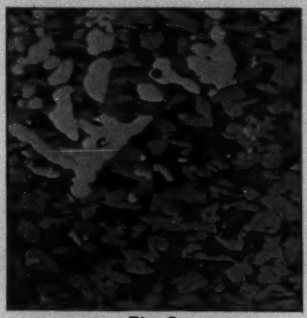

Fig. 2.

Fig. 3.

Fig. 4.

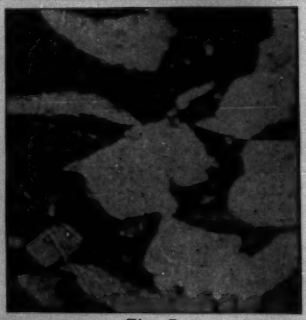

Fig. 5.

Fig. 6.

It is obvious that the latter object will be attained the more completely the more the peculiarities of a structure have been revealed by the use of various methods. It is not always an easy matter, though, to arrange the details obtained into a harmonious whole, especially since the observer may be misled by unusual features in the structure.

The main aim of scientific metallography at present must be to study in all their ramifications the varying phenomena observable when using divers metallographic methods. The phenomena thus observed must be sufficiently well defined to exclude all possible deceptive features.

Whenever metallography has solved this problem, then the way is open to propose such methods as may be applicable to specific cases, and to simplify such methods in a manner so that non-experts may be able to draw conclusions with tolerable certainty.

At present it would seem as if the establishment of standard methods would, in many cases, tend to misunderstandings.

In order to contribute something towards the final attainment of the aim described above, attention is called to some features of micrographic work which have come under my observation more or less frequently.

I hope not to be considered an intruder if I take the liberty to present some results of an examination of machinery bronze, made at the Royal Mech.-Technical Testing Bureau at Charlottenburg, and which may be considered a supplement to the paper read by Mr. Outerbridge.

I regret not to have been able to obtain the analyses of the bronze.

Figs. 1 to *8* of the photographs present features strongly indicating similar characteristics of the structure of this bronze, notwithstanding its treatment with a variety of methods.

The material experimented with was a piece of metal which had been used for a crushing test, the section to be examined being a face perpendicular to the one under compression.

Fig. 1 gives the structure after polishing the piece upon cloth with Parisian-red. Many bluish-white segregations, *c*, are visible in a somewhat depressed yellow matrix. In the latter the micro-structure is but faintly marked. After five minutes' etching in diluted sal-ammoniac the structure *Fig. 2* was obtained. *c* remains unchanged. In the vicinity of *c* (probably so-called tin-spots) yellow, angular crystals, *a*, are imbedded in a reddish-brown matrix, *b*. Etching fifteen minutes more with the same fluid no change takes place, except a more marked difference in the colors. This is seen in *Fig. 3* as compared to *Figs. 1* and *2*, and less magnified in *Fig. 4*.

Matrix *b* shows, under increased magnification, in *Fig. 5*, marks of a eutectic alloy.

After this the test-piece was relief-polished upon rubber with Parisian-red and water and etched for twenty-eight minutes in a solution of 1 part nitric acid, 1 part muriatic acid, and 18 parts water.

This produced the structure *Fig. 6*. The parts *c* are colored black and surrounded by a bluish halo. The impression is created as if the structure had been completely changed. However, this is an illusion and one of the sources of trouble the metallographist has to deal with. When the object was examined under a blue light (by holding a blue glass between the light and the prism), then *Fig. 7* was obtained, in which the original structure *a* and *b* can be recognized; its appearance was made considerably more definite when, instead of the blue glass, the Zettnow filter (light filter) was used, consisting of 160 grains nitrate of copper, 14 grams chromic acid, 250 grams water, throwing waves of light of a definite length upon the object, producing *Fig. 8*.

Therefore, we see that form and position of the details of the structure remained the same, only the colors changed; *a*, has become reddish with a bluish hue, containing numerous round, blue specks, increasing in numbers towards the center of the piece; *b*, is pure red. It is possible the accumulation of the blue specks in *a*, towards the center may be due to a changed chemical composition from the circumfer-

ence towards the center of the piece, as was found by Charpy when using other methods.*

Even after etching the specimen in nitro-muriatic acid (aqua regia) for eighteen hours, no change had taken place in the formation of the structure *a* and *b*, except *b* having been eaten into a little deeper than *a* by the acid.

No change was likewise produced by immersion of the specimen in a solution of blue vitriol for twenty-three minutes and passing through it a current of electricity. For chemical reasons I abstained from etching this bronze with strong nitric acid.

On dissolving copper-tin bronze in nitric acid the tin is precipitated as stannic oxide, in the form of a white sediment. I was afraid this would happen when etching with strong nitric acid, causing a thin film of this white tin-sediment to be deposited partly upon the surface of the specimen, thus covering the view of the structure. How far in this respect my anxiety would have been justified I have not proved thus far by actual experiment.

There is one thing which, under certain circumstances, may cause the erroneous conception that the structure was changed by the etching.

Let us suppose the specimen to have been cut at right angles to the etched surface. If now the structure was brought out by any method, on that section of the metal it would present itself as in *Fig. 20*, revealing the depth of the etching to the line *a—b* on the originally etched surface, done by means of a strong etching fluid. We see at once the apparent change that has taken place in the structure. Such change becomes more noticeable the deeper the etching and the finer the structure. I would also call attention to a third phenomenon which shows itself especially with steel, containing ferrite, and which, likewise, easily leads to the erroneous impression as if etching would change the structure. If we etch a crystal, for instance of calcite, in muriatic acid, its surfaces will not be attacked uniformly.

**Bulletin Soc. d'Encour. p. l'Ind. Nat.*, March, 1897. *Metallographist*, 1898, Vol. I, Nos. 2 and 3, p. 196.

Regular depressions will appear, intimately connected with the symmetrical system of the crystal. These depressions are known to the mineralogist as "etch figures."

Even if the crystal is cut into sections in various directions, these etch figures are obtained. They are uniform on faces which are uniform from a crystallographic point of view, and they are variable if the faces vary from a crystallographic standpoint.

Under certain circumstances these etch figures are so closely arranged as to make the surface appear to be composed of small crystals.*

The etch figures may even become such a compact mass that the surface appears dark under a low power, and not until a high power is used will their true nature be revealed. If, for instance, crystals of calcite are thrown together without semblance and order, as is the case in marble, then a cut through the mass will bisect the crystals in all possible angles.

According, therefore, to the angular position of the etch figures, some of the individual grains of calcite will appear quite dark, while others remain light with low magnification, not only with the light falling at an angle, but also if it falls vertically through the prism.

We likewise observe these etch figures and their compact arrangement with the ferrite grains of steel, because they are crystals which were more or less hindered in their development by close contact to their neighbors.

In this case the etching must be continued with strong acid for some time.

Under a low power, certain grains therefore also appear quite dark, or even black, so as to make their mistaking for perlite possible when but superficially examined.

Only after the highest possible magnification is the true character of the structure revealed. This phenomenon is certainly of importance in connection with the question under discussion. To enter more fully into details would

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*Stead, "The Crystalline Structure of Iron and Steel," Iron and Steel Institute, May meeting, 1898.—*Metallographist*, Vol. I, No. 4, 1898

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Fig. 7.

Fig. 8.

Fig. 9.

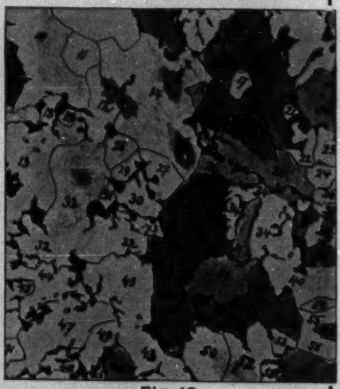

Fig. 10.

Fig. 11.

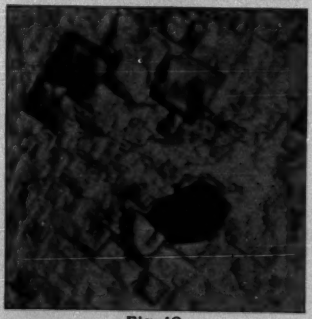

Fig. 12.

take us too far out of the way. I discussed this subject very thoroughly in Heft VI, 1898, of the Mittheilungen of the Royal Technical Testing Bureau in Berlin, under "Untersuchungen auf tiefgeätzten Eisenschliffen." (Investigations on deeply etched specimens of steel.—Flusseisen.)

For better explanation I added a few photographs which refer to an ingot of soft Thomas flusseisen.

Fig. 9 shows a portion of the same, 123 times magnified, etched for six minutes in double chloride of copper and ammonium in proportions of 1 : 12. There are large dark blotches; others are white, while the lines of demarcation between them are not sharply defined.

On etching more strongly these blotches seem to change their position partly. If, however, these blotches are examined under a high power, there may be noticed minute segregations of perlite within the main body of ferrite. The latter appears to be resolved into individual grains (crystals) of different degrees of lightness. *Fig. 10* is a hand-drawing of *Fig. 9* for a better understanding of the matter. The perlite is shown in black, while the crystals of ferrite are numbered and shown in lighter or darker shades, according to their degree of lightness. The line of demarcation between the light crystal, No. 43, and the dark ferrite crystal, No. 42, is 1,650 times magnified in *Fig. 11*.

In this figure we can plainly perceive the reasons for the different shading. It is due to the varying angular position of the neighboring crystals to the axis of the microscope. In one and the same crystal no difference of position or form will be perceptible in the etch figures, but there is a difference as to the depth they are eaten into by the acid. Especially in the neighborhood of minute slag spots the crystals are eaten into more deeply than elsewhere. Under a low power the crystal appears darker at such spots, as shown in *Fig. 12*, under a 1,650 magnification, which illustrates a portion of the dark spot in crystal No. 32.

This phenomenon has been at present followed up only in specimens of steel (flusseisen), but will be found in all metals whenever the structure has assumed the form of crystals. There is another, a fourth, circumstance which may occa-

sionally create the impression as if a change of structure was owing to the time and method of etching. This is due to photographic reproduction.

Micro-photographing is by no means such a matter-of-course operation as it is often thought to be, but depends in its results very much on the skill and understanding of the operator. How seemingly different a structure may appear, according to the manner it has been photographed, is shown in *Figs. 13* to *16*. As a test piece rail steel was used. The specimen was taken from the web and was etched for one minute in double chloride of copper and ammonium of 1 : 12 strength. *Fig. 13* was taken with the objective 35 of Carl Zeiss in Jena with a magnification of 29 diameters, and using a prism above the objective for the purpose of better light. The structure is reproduced excellently.

Fig. 14 is a photograph of the same spot with the same magnification, the vertical light being obtained by means of a "plane parallel glass" 0·5 millimeter thick, and which was inserted between the object and the objective at an angle of 45°. Under that light the structure appears somewhat different, while under a reduced light brownish and dark hues on the photographic plate produced the same results.

A more serious error is illustrated in *Figs. 15* and *16*, fifty times magnified, with the use again of the "plane parallel glass." In *Fig. 16* this was only 0.2 millimeter thick, but when photographing No. 15 the thickness of the glass was 0.5 millimeter. With *Fig. 15*, *a* and *b*, an experiment was made by having the objective at different distances from the object.

Both *a* and *b* are reproductions from the left half of *Fig. 16*. However, the structure in *Fig. 15*, *a* and *b*, is distorted to such an extent as not to resemble the real structure of *Fig. 16*.

Many similar examples could be given. Concerning this matter I beg to call attention to a description of "Die Mikrophotographie im auffallenden Licht und die mikrophotographische Einrichtung der köngl. mechan. tech. Versuchsanstalt in Charlottenburg, von Prof. A. Martens und Ingenieur E. Heyn."

Improper etching may also cause mischief occasionally. Thus, for instance, *Figs. 17* and *18* are nearly full-size photographs of transverse sections of a round bar, turned from the head of a "Thomas" steel rail.

Fig. 17 was etched in a 2 per cent. solution of nitric acid for twenty-four hours. *Fig. 18* was etched for five minutes in double chloride of copper and ammonium of 1:12 strength. The difference in appearance may thus be explained. See *Fig. 21*.

Upon the surface of the test piece the fluid becomes saturated with salts of iron, and this saturated solution will have less and less effect on the specimen to the degree that saturation proceeds.

FIG. 20.

FIG. 21.

On the sides, however, the saturated solution will descend, as indicated by the arrows *a a* to make room for fresh fluid. As a consequence the sides and edges of the specimen are etched more effectively than the middle, as shown in *Fig. 17*. This is not noticeable in *Fig. 18*, which was etched only 5 minutes and the specimen was continually moved about in the fluid during that time.

To confirm this partial effect on the specimen more completely, a test piece, taken from a flat bar of dead, soft basic open-hearth steel, as in *Fig. 19*, was etched for three minutes in double chloride of copper and ammonium 1:12, without giving any motion to the fluid. The more effective action of the fluid along the edges is plainly visible. It is

easy to see how erroneous conclusions may be drawn, due to such appearances, as if there were segregations present.

Whenever segregations are suspected, then the only reliable way to proceed is, if the etching is to be of any value, to repeatedly grind and polish and etch the specimen with different etching fluids, using all possible precautions to see whether the same effect is produced each time.

In the paper read by Mr. Outerbridge, the desirability was expressed of a standard-sized specimen for etching.

Concerning the size of a specimen, this is a matter of convenience or necessity, according to the needs of the occasion, or the amount of material on hand.

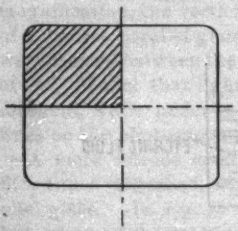

FIG. 22.

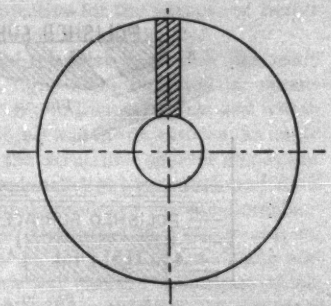

FIG. 23.

In the laboratory at Charlottenburg, it is the rule to obtain, if possible, a complete cross-section of the object to be examined, be that a bar, beam, rail, etc. If the object to be examined is very large, or bulky, like an ingot or heavy forging, a piece is cut out which, apparently, includes the portion of the structure to be examined.

Fig. 22, for instance, shows a specimen cut from an ingot, and *Fig. 23* one from a heavy shaft.

The work is controlled and checked by preparing other similar specimens which are expected to give similar results.

Of course, in order to examine with the microscope and

Fig. 13.

Fig. 14.

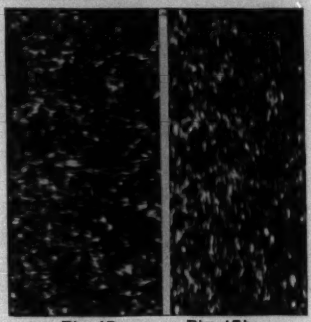

Fig. 15a. Fig. 15b.

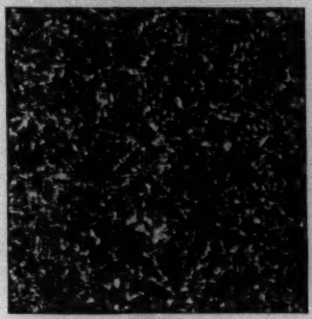

Fig. 16.

Fig. 17.

Fig. 19.

Fig. 18.

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to photograph specimens of large dimensions and comparatively heavy weight, it is necessary to be provided with a properly arranged stand, such as is found with the micro-photographic apparatus of Marten's design. Should only a detail-examination of the structure be desired, then smaller specimens of convenient size answer the purpose as well.

CHARLOTTENBURG, GERMANY, March 5, 1899.

DESCRIPTION OF PHOTOGRAPHS.

FIG. 1.—Magnification, 365 diameters. Vertical light through prism. Machinery bronze. Polished on cloth.

FIG. 2.—Magnification, 365 diameters. Machinery bronze. Polished on cloth. Etched five minutes in sal-ammoniac.

FIG. 3.—Magnification, 365 diameters. Vertical light through prism. Machinery bronze. Polished on cloth. Etched five minutes in sal-ammoniac. Etched fifteen minutes more in sal-ammoniac.

FIG. 4.—Magnification, 123 diameters. Vertical light through prism. Machinery bronze. Treatment same as FIG. 3.

FIG. 5.—Magnification, 1,650 diameters. Vertical light through prism. Machinery bronze. Details of FIG. 3.

FIG. 6.—Magnification, 365 diameters. Vertical light through prism. Machinery bronze. (1) Polished on cloth. (2) Etched five minutes in sal-ammoniac. (3) Etched fifteen minutes more in sal-ammoniac. (4) The relief polished on rubber, with jeweller's rouge. (5) Etched twenty-eight minutes in 1 part nitric acid; 1 part muriatic acid; 18 parts water.

FIG. 7.—Magnification, 365 diameters. Vertical light through prism. Photographed through blue screen. Subject, same as FIG. 6.

FIG. 8.—Magnification, 365 diameters. Vertical light through prism. Taken with Zettnow filter. Subject, same as FIGS. 6 and 7.

FIG. 9.—Magnification, 123 diameters. Vertical light through prism. Block of soft "Thomas" cast steel. Etched six minutes in double chloride of copper and ammonium, 1 : 12.

FIG. 10.—Magnification, 123 diameters. Sketch by E. Heyn, giving key to FIG. 9. Perlite, black; ferrite, white to gray.

FIG. 11.—Magnification, 1,650 diameters. Vertical light through prism. Compare with FIGS. 9 and 10. Line of demarcation between the light ferrite grain, 43, and the darker ferrite grain, 42.

FIG. 12.—Magnification, 1,650 diameters. Vertical light through prism. Compare with FIGS. 9 and 10. The dark spot occurs in ferrite grain, 32.

FIG. 13.—Magnification, 29 diameters. Objective, 35. Vertical light through prism. Rail steel. Etched one minute in double chloride of copper and ammonium, 1 : 12.

FIG. 14.—Magnification, 29 diameters. Objective, 35. Vertical light

through plane glass of 0·5 millimeter thickness. Material and place, same as FIG. 13.

FIG. 15*a*.—Magnification, 50 diameters. Vertical light through plane glass of 0·5 millimeter thickness. Represents the left half of FIG. 16. Rail steel. Etched one minute in double chloride of copper and ammonium, 1 : 12.

FIG. 15*b*.—Magnification, 50 diameters. Vertical light through plane glass of 0·5 millimeter thickness. Position of object changed to the right of 15*a*.

FIG. 16.—Magnification, 50 diameters. Objective, 35. Vertical light through plane glass of 0·2 millimeter thickness. The left half corresponds to FIGS. 15*a* and 15*b*. Rail steel. Etched one minute in double chloride of copper and ammonium, 1 : 12.

FIGS. 17, 18 and 19.—Described in the text.

REMARKS BY THE TRANSLATOR.

Ingenieur E. Heyn's communication is a most valuable and timely contribution to the subject of metallography in general, and the discussion of the paper by Mr. A. E. Outerbridge, Jr., in particular. It shows how large and fertile a field for exploration the new science of metallography presents. Nevertheless, while Mr. Heyn is eminently right in saying that the structure of the specimens to be examined is not changed by the method of etching and examination, it is admitted that the *appearance* of the structure may not be the same under similar circumstances, unless certain precautions are observed. Mr. A. Sauveur, commenting on the paper by Mr. Outerbridge, and the discussion following, in the last number of the *Metallographist*, Vol. II, No. 2, April, 1899, pp. 152, 153, admits the validity of Mr. Outerbridge's plea for uniform methods, when he says: "It, however, remains true, doubtless, that similarity of treatment is as desirable in the case of metallographic methods as in the case of physical or chemical methods; but to the editor's mind the danger of "being misled" by the use of unlike processes is, if anything, less than in the case of the latter.

The writer fully agrees with the opinions expressed both by Engineer Heyn and Mr. Sauveur, but takes the liberty to point out that, while, as all roads lead to Rome, so all the various methods employed by the individual and scientific metallographist lead eventually to the same results, in order to make this new science practically useful for the

everyday uses of the engineer, we must boil all these various methods down to something simple enough, and yet approximately accurate enough in its results, so that the work of the scientist not only becomes of greatest economic value to the community at large, but is comparatively easy of interpretation and comparison by those whose object is the immediate application of the results of microscopic examination for the purpose of rectifying defective treatment of metals in the mill, shop or erecting yard, and, if necessary, allow duplication of methods in such a manner and reasonable time as to convince persons not so well versed in all the intricacies of scientific metallography, nor in the complex phenomena of the properties of metals; that the results of such findings may be made comprehensible and acceptable to the minds and understanding of the many.

(Communicated by Mr. Albert Sauveur, Boston, Mass.)

MR. SAUVEUR:—From Mr. Outerbridge's paper and the appended discussion, one cannot help to gather the impression that the author and the participants to the discussion rather deplore the fact that the appearance of the structure of a metal, as revealed by the microscope, varies with the treatment to which the metal has been subjected. They are apparently inclined to look upon this in the light of a shortcoming which must diminish the value of metallographic methods applied to the testing of metals and alloys. Mr. Outerbridge points out that such variation of microstructure, brought about by variation of treatment, may be misleading; he calls it "a source of error." The microstructure of a metal undoubtedly varies with the treatment it has undergone, sometimes to a very great extent, but this is a fortunate occurrence, for the physical properties of the metal also vary, under the same conditions, in a no less marked degree. If the microscopical appearance of the structure were to remain the same whatever the treatment, the microscope would be as helpless as is chemical analysis in assisting us to solve the numerous and important problems presented by the heat treatment of metals. Its field of usefulness would be greatly curtailed, for it is precisely here, where chemistry fails us, that the assistance of metallo-

graphic methods becomes valuable; the slightest changes of heat treatment, which are always accompanied by corresponding variations of physical properties, record themselves in the structure of the metal; it only remains for us to learn how to read and to interpret these changes; and to this end the efforts of metallographists should bend.

It is evident that if we wish to compare the relative qualities of two samples of the same metal from the appearance of their micro-structure, the samples should be prepared under exactly the same conditions. We could not expect to derive any useful comparative datum from the microscopical examination of a sample cut from a small ingot, and therefore quickly cooled, and of a sample from a large ingot, and therefore cooled more slowly. The two samples do not have the same physical properties, and we would not think of passing judgment upon the relative value of the metals they represent, from the results they would give in the testing machine. To insist upon this point is superfluous.

Attention is also called in the paper and in the discussion to the fact that the appearance of an etched specimen will vary with the etching fluid, time of immersion, etc. It is undoubtedly true, but the wonder is that the structure will stand so much ill-treatment before being hopelessly disfigured. Mr. Outerbridge's specimens, I think, were all too deeply etched; and while a deep etching is sometimes desirable and useful, it must be remembered that it always blurs the lines of demarcation between the structural components, which otherwise would be sharp and clear. If similar liberties were taken with some analytical methods, the results would probably be disastrous, and the identity of the samples, as ascertained by their composition, irretrievably lost.

I could not be as lenient as the author towards the observer who would infer that his (the author's) photographs were taken from different specimens; indeed, I would be more inclined to pardon him for believing that the reproductions were all made from the same photograph, so great, it seems to me, is the similarity between them, judging, at least, from the half-tone engravings.

There is a tendency on the part of the author and of the participants to the discussion to exaggerate the danger of being misled by defective treatment of the specimens. After a short apprenticeship, and a fair degree of skill and good judgment, there will be very little difficulty experienced in preparing polished sections for microscopical examination, in such a way as to reveal the true constitution of the metal, free from all markings or blemishes foreign to its structure, or if any such irregularity appears to readily detect it. And, indeed, so long as this result is reached, it matters little what method has been used. It, however, remains true, doubtless, that similarity of treatment is as desirable in the case of metallographic methods as in the case of physical or chemical methods; but, to my mind, the danger of "being misled" by the use of unlike processes is, if anything, less than in the case of the latter.

MR. OUTERBRIDGE:—One purpose of the paper entitled "A Study of the Micro-structure of Bronzes" was, as stated therein, to invite criticism and discussion, and the author is pleased to observe that this invitation is being so generally accepted.

He finds it difficult, however, to understand how Mr. Sauveur could have inferred that the author, and the participants in the discussion on his paper, "deplore the fact that the appearance of the structure of a metal, as revealed by the microscope, varies with the treatment to which the metal has been subjected * * * they are apparently inclined to look upon this in the light of a shortcoming which must diminish the value of metallographic methods applied to the testing of metals and alloys."

The main object of the paper was to indicate the vital importance of showing with perfect accuracy the variations of micro-structure of various metals which have been subjected to different heat treatment, mechanical treatment or metallurgical treatment. Having noticed in his own studies that the records of such treatment may be unintentionally falsified by different methods of preparing the specimens for examination under the microscope, the author endeavored to show by argument and illustration the importance of adopt-

ing uniform methods of etching and polishing such specimens. Mr. Sauveur appears to have misinterpreted entirely the plain meaning of the argument; yet, later on, he agrees with its real purport, for he says: "It is evident that if we wish to compare the relative qualities of two samples of the same metal from the appearance of their micro-structure, the samples should be prepared under exactly the same conditions."

This is the crux of the whole argument in the original paper, and it was there stated that the numerous valuable contributions to the subject of microscopic metallography, illustrated with half-tone engravings, which have been published during the past ten years or more, are not easily comparable with each other, simply because one does not know whether the specimens have been prepared under exactly the same conditions; indeed, there are good reasons for believing that they have been prepared under very different conditions.

Mr. Sauveur thinks that the six half-tone illustrations accompanying the paper, showing six photo-micrographs of the same spot of the same specimen, taken after successive etchings, look so much alike that "one might believe that the reproductions were all made from the same photograph." The author selected for this purpose, as stated in the paper, a specimen which had certain characteristic groupings of dark bands in order that they might be readily recognized in each picture; the difference in appearance of the specimen after each etching was to be looked for in *the detail*, which was, of course, more clearly apparent in the specimen as observed under the microscope than in the half-tone reproductions made from photographic negatives.

Mr. Sauveur says, in conclusion: "Similarity of treatment is as desirable in the case of metallographic methods as in the case of physical or chemical methods." This is practically all that was contended for in the original paper.

The science of microscopic metallography is assuming an important position in industrial laboratories, and free criticism of the author's paper on the subject may prove far

more valuable in clearing up uncertain points than did the original thesis. For this reason the author hopes that others may criticise his paper more vigorously than Mr. Sauveur has done. He is highly gratified that his comparatively unimportant and wholly tentative observations in "A Study of the Micro-Structure of Bronzes" should have drawn forth, from the distinguished engineer in charge of the Micro-Metallurgical Bureau of the famous Charlottenburg testing laboratories, one of the most valuable contributions to the science of microscopic-metallography that has appeared in any American publication.

CHEMICAL SECTION.

Stated Meeting, held December 6, 1898.

REACTION VELOCITY.

By Dr. Robt. Hart Bradbury,
Member of the Institute.

The speed of a body moving uniformly is the distance passed over divided by the time taken to pass over it—

$$v = \frac{s}{t}.$$

If the motion of the mass be not uniform, the division of the whole distance by the whole time will give simply the average speed and the velocity will be different at different points of the course. If we divide a small portion of the course, *e. g.*, 1 centimeter, by the time taken to traverse it, the result will be the average velocity over that centimeter and the variation in speed will be small; the approximation to the real velocity in that portion of the course will be close. Finally, if we consider an infinitely small portion of the path, ds, it is clear that the increment of velocity in passing over it will be an infinitely small quantity of the second order, or, in other words, the quotient

of an element of a path by the infinitely small time taken to traverse it,

$$\frac{ds}{dt},$$

is the rigorous mathematical expression for the speed.

Now, the law of mass action, which is the foundation of our knowledge of chemical equilibrium and of the velocity of chemical changes, asserts that the speed of a chemical process is proportional to the product of the concentrations of the reacting substances, each concentration being affected by an exponent which is equal to the number of molecules of that constituent which takes part in the change.

$$v = kC_1^{n_1}C_2^{n_2} \ldots C_r^{n_r}.$$

This gives the speed of transformation from left to right in the chemical equation for the change.

For instance, if we consider the change of alcohol and acetic acid into acetic ester and water, the speed in the sense of the equation,

$$C_2H_5OH + CH_3CO_2H = CH_3CO_2C_2H_5 + H_2O,$$

is expressed by

$$v = kC_1C_2,$$

since we have but two concentrations to consider, and since both substances enter the change with one molecule. By the concentration we understand the quantity in unit volume, expressed in gram-molecules.

Many chemical changes are reversible, *i. e.*, they proceed from right to left, as well as from left to right; the reaction products interact and reform the original substances. Thus, if we mix equivalent quantities of water and acetic ester, chemical transposition occurs and some acetic acid and alcohol are produced.

In reversible changes the direct reaction, *e. g.*, the production of ester and water from the alcohol and acid, and the reverse reaction, *e. g.*, the production of alcohol and acid from the ester and water, must be considered to occur together in the liquid. The observed velocity at any time

is the difference of the two. Writing v' for the speed of the reverse change there.

$$v' = k'C_1'C_2'.$$

Where C_1' and C_2' are the concentrations of the ester and the water, and if V is the observed speed, then

$$V = v - v' = kC_1C_2 - k'C_1'C_2'.$$

Introducing the possibility that each of the substances may enter the change with more than 1 molecule and making the number of substances unlimited, we have for the most general expression for the observed speed of change

$$V = v - v' = kC_1^{n_1}C_2^{n_2}C_3^{n_3} \ldots - k'C_1'^{n'_1}C_2'^{n'_2}C_3'^{n'_3}.$$

In practice matters are greatly simplified by the facts that the exponents n_1, n_2, etc., are always small numbers—no case is known where $n > 3$; that the number of substances which can simultaneously take part in a change is small, three being at present the limit in this case also; and that in many reactions the speed of the reverse reaction from right to left is so small, that it can be left out of account without introducing any serious error.

We have now to examine more narrowly the meaning of the term velocity, as applied to chemical changes. Instead of distance passed over, we have here to introduce the idea of quantity transformed and our unit, instead of centimeters, becomes gram molecules. If x is the quantity transformed in unit volume at any time, and t the time, then the average velocity for the time elapsed is

$$\frac{x}{t}$$

But the speed of a chemical change is a variable magnitude: theoretically it begins with its maximum value and sinks gradually to zero; hence the mathematical expression for velocity is the relation of an infinitely small quantity transformed to the infinitely small time taken to transform it, the differential coefficient of quantity by time.

$$\frac{dx}{dt}.$$

In the following formulation we shall make the assumption that the reaction proceeds in but one direction, or that the speed of the reverse change may be neglected.

Restricting the discussion to unit of volume, it is clear that if the concentrations of the several molecular species at the beginning are A, B, C, etc., that their concentrations after a time, t, during which a quantity, x, in gram molecules has been transformed, will be (A — x), (B — x), etc., and the velocity of the change at the time will be

$$\frac{dx}{dt} = k\,(A - x)\,(B - x)\,(C - x), \text{ etc.}$$

This expression becomes much simpler in the case where the concentrations of all the species, taken as always in gram molecules, are the same at the beginning—and where each enters the reaction with a single molecule. In this case the concentration of each species will remain the same through the process. That is (B — x), (C — x), etc., will equal (A — x), and the velocity is

$$\frac{dx}{dt} = k\,(A - x)^n$$

where n is the number of substances which enter into the reaction. Or, in words: the velocity is proportional to the product of the concentrations of the reacting substances. In the case above, where the concentration of each of the substances is (A — x), we may call this the system-concentration, and the velocity is then proportional to the system concentration affected by an exponent which is equal to the number of reacting substances. Using this simplification, we have for the reaction in which the concentration of but one substance is made to vary the reaction of the first order, as Ostwald calls it, or the monomolecular reaction according to Van't Hoff

$$\frac{dx}{dt} = k\,(A - x).$$

For a reaction in which two substances enter in molecular proportions, reaction of the second order of Ostwald, bimolecular reaction of Van't Hoff,

$$\frac{dx}{dt} = k(A - x)^2.$$

Finally, for a reaction in which the concentration of three substances is affected, reaction of the third order of Ostwald or trimolecular reaction of Van't Hoff,

$$\frac{dx}{dt} = k(A - x)^3.$$

Reactions in which four or more molecules are concerned are unknown.* One obtains an excellent idea of the progress of a chemical change by integrating these equations, and then making the "graph" of the resulting functions, laying off x on the axis of ordinates and t on the axis of abscissas.†

The course of the reaction is represented by a curve which rises from the time axis at first abruptly, then bends over to the right and ends by approaching asymptotically a line parallel to the time axis. The curve for the monomolecular reaction lies above that for the bimolecular, and this in turn above the curve for the trimolecular. These curves have no maxima and minima and no points of inflection, but this, of course, is evident from the differential equations, without recourse to the "graph."

The final state of things is $x = A$, that is, all the substance has been transformed. This state must evidently be reached with a velocity of zero, and cannot be passed. There is thus no inertia in a chemical change, no oscillation about the position of equilibrium, analogous to the vibration of a distorted solid.

Historically the first chemical change which was subjected to quantitive treatment was the inversion of sugar. The date of Wilhelmy's work on this subject, 1850, is an important one to chemical science, for until that time our science had contented itself almost entirely with acquiring

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* Very recently a tetramolecular reaction has appeared. Compare Judson and Walker, *Journ. Chem. Soc.*, 73,410 (1898). A brief account of their work is given in a supplementary page.

† Ostwald, *Lehrbuch*, Vol. II, Part II, p. 228.

information about the final products of chemical changes, and the problem of studying the change itself had not been successfully attacked.

To devise the first successful mathematical description of a chemical change was undoubtedly a great achievement, and the very important work in reaction velocity which has been done within the last twenty-five years by Van't Hoff, Ostwald, Noyes and their students, is an outgrowth entirely of the seed which Wilhelmy planted.*

The inversion of sugar takes place under the influence of hydrogen ions and with absorption of a molecule of water. The concentration of the hydrogen ions is not altered, their action being catalytic, and the water is present in such large quantity relatively to the sugar that its concentration may be considered constant. The influence of these substances is the same throughout the change, and is incorporated in the constant k.

The change is therefore monomolecular, and is described by the equation

$$\frac{dx}{dt} = k(A - x)$$

In order to test the equation, to prove that it does as a matter of fact, describe the progress of the reaction in time, it is necessary to integrate it, to solve for k, and to ascertain whether k is in fact constant through the whole of the change.

Integrating we get

$$-\log.(A - x) = k\,t + C.$$

C, the constant of integration, is easily eliminated by recalling the fact that x, the change in concentration of the sugar and t, the time, are both zero at the beginning.

Introducing this condition we have

$$-\log. A = C, \text{ and}$$

$$k = \frac{1}{t} \log. \frac{A}{A - x}$$

* Wilhelmy's original paper has been reprinted with notes by Ostwald, *Klassiker d. Exakten Wissenschaften*, No. 29.

All the quantities in this expression for k are known or may be determined; t is simply the elapsed time.

A is the original concentration of the sugar, and x is easily ascertained at any moment by the polariscope. The results showed that the value of k is in fact constant, and that the differential equation must be regarded as a valid description of the change.

The differences in the value of k (from ·001321 to ·001499) are due to variations in temperature of the solution.

Temperature has a great influence on reaction velocity, and at present in all work of this kind the temperature of the solution is carefully maintained constant.

Another classical case of the monomolecular reaction is the decomposition of arsine. From the chemical equation

$$4AsH_3 = As_4 + 6H_2$$

we might predict that the reaction would require the simultaneous meeting of four molecules, and would be tetramolecular.

Such a change would be described by the equation

$$\frac{dx}{dt} = k(A - x)^4$$

It has already been remarked that no tetramolecular reaction is known. In fact, trimolecular reactions are extremely rare. The reaction in question is eminently monomolecular, and the same logarithmic formula employed for the sugar inversion, gives values for k which are remarkably constant.

So far, the kinetic theory of the molecule has not been of much value in dealing with chemical phenomena. Nevertheless, a recent remark of Van't Hoff is of interest in this connection. The slow progress of a monomolecular reaction of this kind shows that not all the molecules are in the same condition. If they were, either none would decompose or they would all decompose at once. This reminds us of Maxwell's conception that the molecules of a gas possess all possible temperatures distributed about the mean value.*

* *Vorlesungen über Theoret. Chem.*, Vol. I, p. 187.

Another distinctly monomolecular reaction is the splitting up of di-brom-succinic acid into mono-brom-maleic acid and hydrobromic acid.

$$\begin{matrix} CHBrCO_2H \\ | \\ CHBrCO_2H \end{matrix} = HBr + \begin{matrix} CBrCO_2H \\ \| \\ CHCO_2H \end{matrix}$$

*

The bimolecular reaction.

In this case the concentration of two substances is changed as a result of the reaction, hence the equation is

$$\frac{dx}{dt} = k(A - x)^2$$

Integrating we obtain at once

$$\frac{1}{A - x} = kt + C$$

and remembering that x and t are simultaneously zero,

$$\frac{1}{A} = C$$

$$k = \frac{x}{At(A - x)}$$

The reactions whose progress is described by this formula are numerous. Among the most important are the saponifications of the esters; for instance, the action of sodium hydroxide on acetic ester, which, in the usual notation, is:

$$CH_3COOC_2H_5 + NaOH = CH_3COONa + C_2H_5OH$$

or in terms of the theory of electrolytic dissociation,

$$CH_3COOC_2H_5 + O\overline{H} = CH_3\overline{COO} + C_2H_5OH$$

Reactions of this type have been investigated with special thoroughness by Warder, Reicher, Ostwald and Arrhenius, and it has been shown that, in general, the reac-

* *Van't Hoff-Cohen.* "*Studien zur Chemischen Dynamik,*" p. 117; where there is an interesting instance of the possibility of detecting the presence of a mixture of isomers by investigation of the reaction velocity.

tion is bimolecular. Among other bimolecular reactions is the hydrolysis of acetamide by acids *e. g.* *

$$CH_3CONH_2 + H_2O + CCl_3COOH = CH_3COOH + CCl_3COONH_4$$

This is apparently trimolecular, but the water is present in such large quantity that its concentration may be considered constant. Further, the reaction between sodium hydroxide and sodium mono-chlor-acetate,

$$CH_2ClCOONa + NaOH = CH_2OHCOONa + NaCl,$$

investigated by Schwab, under Van't Hoff's direction.†

Some of the most interesting of the recent work in this field is the investigation of the action of bases upon γ and δ lactones, carried out in Ostwald's laboratory, by Paul Henry.‡

From the older standpoint the reaction is, for butyro-lactone

$$\begin{array}{l} CH_2 - CH_2 - CH_2 - CO + NaOH = CH_2 - CH_2 - \\ \quad\quad\quad\

coming $\frac{1}{200}$ normal at the same time. After the lapse of a time, t, counted in minutes, the value of x was determined by titrating the remaining alkali with dilute hydrochloric acid of known strength. In the case of the strong bases, potassium, sodium and barium hydroxides, the values of k were constant within the limits of error. With the weak bases a different behavior was to be expected: thus with ammonia, it is obvious that ammonium ions must accumulate in the liquid during the process; this will force back the dissociation of the ammonium hydroxide, reduce the concentration of the hydroxyl ions and cause the value of k to diminish with increasing time. In conformity with this, it was found that with ammonium hydroxide and methylamine hydroxide the value of k decreased as the time increased. It is interesting to notice the verification of another prediction of the theory of electrolytic dissociation. Since the stronger bases are dissociated with practical completeness at moderate dilutions, it was to be expected that no increase in their efficiency in converting the lactones into salts of the γ-oxy-acids would be noticed with increasing dilutions; with ammonia or other weak bases, we should expect increasing dissociation and increasing values of k. This conclusion was strikingly verified by experiment. Finally, we must notice Henry's interesting experiments on the saponification of acetic ester by barium hydroxide. In this case the old and the new view of the state of substances in solution make opposed predictions. From the older point of view the reaction is

$$Ba(OH)_2 + 2CH_3COOC_2H_5 = Ba(C_2H_3O_2)_2 + 2C_2H_5OH.$$

Here, since the ethyl acetate enters, the reaction with two molecules, and the baryta with one, the speed is given by an equation of the form

$$\frac{dx}{dt} = k(A - x)^2(B - x) \qquad (1)$$

where A is the original concentration of the ester and B that of the base.

On the other hand, according to the more recent conception, the reaction is

$$CH_3COOC_2H_5 + \overline{O}H = CH_3CO\overline{O} + C_2H_5OH,$$

and requires an equation of the simple form

$$\frac{dx}{dt} = k(A - x)(B - x), \qquad (2)$$

A being again the concentration of the ester and B that of the hydroxyl, which, of course, is the same as the equivalent concentration of the base. The results showed that it was possible to get constant values of k by means of a form of equation (2), indicating that the hydroxyl ions exist free in the liquid, and that it is to them that the basic properties are due. In all work of this kind it is indispensable to keep the temperature constant; otherwise constant values of k cannot be obtained. Moro* investigated the production of the alkali salts of ethyl-sulpho-thio-carbonic acid from carbon disulphide, alcohol and potassium or sodium hydroxide

$$CS_2 + KOH + C_2H_5OH = CS\begin{matrix}OC_2H_5\\SK\end{matrix} + H_2O.$$

The purpose of the research was to find a typical trimolecular reaction, in which the three substances were different. This was not attained, because it was found necessary to work in dilute alcoholic solution, which, of course, made the concentration of the alcohol constant. In the case of the potassium salt, satisfactory constants were not obtained, but the reaction is probably bimolecular.† Bimolecular also were the reactions in which the same xanthates were produced from carbon disulphide and potassium or sodium ethylate:

$$C_2H_5OK + CS_2 = CS_2OKC_2H_5.$$

For the trimolecular reaction, making the same restrictions as before, that the speed of the reverse change may be neglected and that the equivalent concentrations of the three substances are constantly the same, we have

$$\frac{dx}{dt} = k(A - x)^3$$

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* *Gazzetta Chimica Italiana*, Vol. XXVI, p. 494 (1896).

† Curiously enough, with the sodium salt the reaction is accurately bimolecular.

Integrating

$$\frac{1}{2(A-x)^2} = kt + C.$$

The value of the constant of integration is again given by the fact that x and t are simultaneously zero. This gives us

$$\frac{1}{2A^2} = C$$

$$k = \frac{1}{2t}\left(\frac{1}{(A-x)^2} - \frac{1}{A^2}\right)$$

or

$$k = \frac{1}{t}\left(\frac{2Ax - x^2}{2A^2(A-x^2)}\right)$$

Trimolecular reactions are rare; nevertheless, the three possible types are all known. The case where the three molecules are the same is represented by the polymerization of cyanic acid

$$3CNOH = C_3N_3O_3H_3,$$

which has been studied by Van't Hoff. Two molecules of one substance react with one of another in the reduction of ferric chloride by stannous chloride, the basis of the well-known rapid volumetric method for iron

$$2FeCl_3 + SnCl_2 = 2FeCl_2 + SnCl_4.$$

This reaction has been shown to be trimolecular by Noyes. Finally, all three molecules are different in the oxidation of ferrous chloride by potassium chlorate and hydrochloric acid,

$$KClO_3 + 6HCl + 6FeCl_2 = 6FeCl_3 + 3H_2O + KCl.$$

According to the chemical equation, this change requires the simultaneous meeting of thirteen molecules; yet the researches of Noyes and Wason leave no doubt that it is trimolecular.

[*To be concluded.*]

FRANKLIN INSTITUTE.

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GRAPHITE: ITS FORMATION AND MANUFACTURE.

By E. G. Acheson,
Member of the Institute.

EARLY HISTORY AND RECOGNITION.

In the year 1779, Karl Wilhelm Scheele, a young apothecary in the town of Koping, Sweden, a remarkable genius as an investigator, and then in the 37th year of his age, discovered that graphite had an individuality quite apart from molybdenum sulphide, with which it had been until then confounded. He discovered that when it was treated with nitric acid, carbon dioxide was produced, whereas molybdenum sulphide when oxidized produced a white earth, and he drew the conclusion that it must be some kind of carbon, likely of the general nature of coal.

Previous to this discovery by Scheele, a group of minerals including graphite and certain ores of lead, molybdenum, antimony and manganese (lead sulphide, molybdenum sulphide, antimony sulphide, manganese dioxide) were believed to be one and the same substance, or, at least, members of the same family. This opinion was due to their outward resemblance, and the fact that they produced marks on paper. This confusion naturally led to the application of the same name or names to each of the members of the group, and as graphite had not been recognized by any peculiarity distinctively its own, it received the names molybdæna, plumbago, graphite and black-lead, which were used in an indiscriminate manner for each of the several substances. The name molybdæna was dropped at an early date, probably immediately following the discovery by Scheele, and there is no known reason why plumbago and black-lead should not have followed its lead, for graph-

ite is the only one of the series not misleading and entirely appropriate, meaning as it does "I write," from the Greek word γράφω.

Graphite does not seem to have received any particular attention from chemists from the time of the discovery by Scheele until the year 1800. During the last quarter of the eighteenth century, the diamond was a subject of much interest, in a chemical sense, and in the hands of the French chemists it was shown to produce carbon dioxide when ignited in air. In 1796 Smithson Tannant showed that equal weights of charcoal and diamond yielded equal weights of carbon dioxide on burning, and they were thereafter associated together as carbon. In 1800 Mackenzie added graphite to the carbon group, by showing that it also, in equal weight, produced the same weight of carbon dioxide.* Thus, in the opening year of the present century, graphite was proven to be an elementary substance. Charcoal, diamond and graphite were then recognized as three distinct allotropic forms of the element carbon.

DISTRIBUTION.

Graphite, in a more or less pure state, is quite freely distributed over the earth, but only in a few places is it found under conditions of purity, quantity, ease of mining, refining and transportation to market that permit of a profitable business being made of it. Statistics for the six years 1890 to 1895, inclusive, give the world's production as 73,751, 57,220, 54,280, 55,810, 46,951 and 53,955 short tons. This is an average yearly production of 56,994 tons—over 156 tons every day of the year—of a material known to the majority of men as black-lead or plumbago, useful only for writing on paper and polishing stoves.

The production during the years mentioned was contributed to by Austria, Ceylon, Germany, Italy, United States, Canada, Japan, India, Russia, Great Britain, and Spain, the proportionate quantities furnished by these countries being in the order given.† It will be observed

* Roscoe.
† *Mineral Industry*, 1898.

that Great Britain is, with but one exception, the smallest producer; indeed, 45 tons cover the total amount reported, and this was mined in 1895. For several centuries Great Britain was one of, or the, largest producer; in fact, in the earliest days of the industry, it was probably the only one. The graphite from the Borrowdale mines in Cumberland was famous as the best for making pencils. In the sixteenth and seventeenth centuries these mines were so productive as to yield an annual revenue of £40,000, although they were only worked a few weeks in the year for fear of exhausting them.*

Great differences exist in the structure and purity of the graphites furnished from the various mines. Mother Nature was seemingly not content with making carbon appear in three forms—charcoal, diamond and graphite—but extended her labors on graphite; and, to the further confusion of the metallurgist and the chemist, made it a family of two members, crystalline and amorphous, two distinct allotropic forms of the allotropic substance, graphite. The product of the Ceylon mines is crystalline, of great purity, analyzing in some instances over 99 per cent. carbon, while that of the Borrowdale mines is amorphous and also very pure.

The chief impurity in graphite is iron; indeed, its constant presence and frequent large quantity led to the belief, in the early days, that graphite was a carbon-iron compound, and it was even sometimes called carburet of iron.

USES.

It is quite probable that the first use made of graphite was as an instrument for writing. The first account we have of its employment for this purpose is contained in the writings of Conrad Gessner on Fossils, published in 1565. A picture of a pencil is shown, and, referring to it, he says: "The pencil represented below is made, for writing, of a certain kind of lead (which I am told is an artificial substance termed by some, English antimony), sharpened to a point and inserted in a wooden handle."† This pencil

* Roscoe.
† Roscoe.

was probably made of graphite from the Borrowdale mines, which, we are told, were in operation in the sixteenth century. Its uses for other purposes than pencils are of much more recent date, probably all of them falling within the present century, and nearly all within the last few years.

The present uses of graphite include the manufacture of pencils, crucibles, stove polish, foundry facing, paint, motor and dynamo brushes, anti-friction compounds, electrodes for electro-metallurgical work, conducting surfaces in electrotyping, and covering the surfaces of powder grains. For most of these purposes it is used in the natural impure state, while for others it is necessary to render it quite pure and free from grit. Its purification is accomplished by a method worked out by Brodie, which consists in first grinding, or otherwise reducing the graphite to a state of fine subdivision, washing out the heavier impurities, mixing 14 parts with 1 part of potassium chlorate and 2 parts of concentrated sulphuric acid, heating on a water-bath for some hours, washing thoroughly and afterwards roasting at a red heat. If silica is present a treatment with hydrofluoric acid is added to the process.

The mining and manufacture of graphite into articles for which it has been found useful, give employment to thousands of people. The mines of Ceylon alone, when working to their capacity, employ about 24,000 men, women and children; the work, however, is done entirely by hand, and in a very crude manner.* In the city of Nüremburg, Germany, the home of the famous Faber pencil, are twenty-six factories, employing about 5,500 people in the making of pencils.†

MANUFACTURE.

The rapid increase in the use of graphite and consequent decrease in Nature's stocks, make the problem of manufacturing it to order, a subject of much importance.

When we consider the hundreds of thousands of chemical changes men are constantly putting the elementary

* "Watt's Dic. of Chem.," 1890.

† "Encl. Brit."

bodies through, and the very prominent part taken by carbon in these reactions, it would be rather remarkable if at some point, Nature's method for producing graphite was not discovered. That it is not a very difficult act is evident from the fact that it has been accomplished, in a small way, in several instances.

Mr. Muir, in Watt's Dictionary of Chemistry, edition of 1890, mentions six recognized methods.

(1) By heating charcoal with molten iron, and dissolving out the iron with hydrochloric and nitric acids.

(2) By the slow decomposition of hydrocyanic acid, and boiling the product with nitric acid.

(3) By evaporating the mother liquors obtained in making soda: these contain cyanogen compounds which are decomposed at a certain concentration of the liquid with formation of ammonia and graphite.

(4) By leading carbon monoxide over ferric oxide at 300° to 400°.

(5) By the decomposition of carbon disulphide at high temperature, in contact with metallic iron.

(6) By leading carbon tetrachloride over molten pig iron.

Whether or not any of these methods could be developed to a state providing a commercial process, I am not prepared to say, but am inclined to think not. They have always been considered accidents or chemical feats of the laboratory, and in some instances their formation was very objectionable.

The Cowles Bros., of Cleveland, O., are reported to have found that graphite sometimes occurred in or about the charge of an electric furnace. This formation is referred to in one of their patents, and a feature of the patent is a provision to get rid of the material, as it was very objectionable on account of its high electric conductivity. Its formation was not reduced to a method, the causes for, or the exact conditions under which it was made, not having been investigated. It was like some of those in the list of Muir, an accident, and a great nuisance.

Still another way of making graphite was described by G. Rose, in 1872. He exposed a cut diamond, bedded in

charcoal, to a temperature equal to molten cast iron, whereupon the surface became coated with graphite. It is safe to say this process will never attain commercial success nor popularity.

Finally, in the Encyclopædia Britannica (1890) we are told that "by heating to the high temperature afforded by a powerful galvanic battery, both the diamond and amorphous carbon are converted into graphite." This statement I will refer to later on.

In a paper which I had the honor of presenting to the Institute at its stated meeting of June 21, 1893,* reference was made to the formation of a black material consisting of a mixture of carborundum and free carbon during the operation of the carborundum furnaces. This was again referred to, and at much greater length, by Mr. Francis A. Fitzgerald, chemist to the Carborundum Company, in a lecture delivered before the Institute on December 11, 1896,† after it had been the subject of much thought and study, and when I had about concluded the formulation of a theory covering the transformation of amorphous into graphitic carbon.

Very early in my experiments on the manufacture of carborundum, I noticed that graphite occasionally formed in the portion of the furnace charge lying next to the cylinder of granular amorphous carbon, which passed through the center of the furnace, and which became heated to an extremely high temperature, by the passage of a heavy electric current, and around which the charge was placed to receive the heat necessary for the formation of carborundum. Also that when ordinary bituminous coal coke was used to form the core, quite a large amount of it was converted into graphite, whereas, when petroleum coke was used, very little of it was made graphitic.

By a careful study of these formations, it was found that the graphite formed outside of and surrounding the core, was produced by the decomposition of the carborundum,

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* "Carborundum: Its History, Manufacture and Uses."

† "The Manufacture and Development of Carborundum at Niagara Falls."

which is, chemically, a carbide of silicon, and, by induction from a number of known facts, that that formed within the core was also produced from a similar decomposition of carbides, which were created by the chemical union of the carbon of the core with its contained impurities. The facts from which I have drawn this conclusion are:

(1) Comparatively pure petroleum coke produces practically no graphite.

(2) Impure bituminous coal coke produces large quantities.

(3) The larger the known percentage of impurities in the bituminous coal coke, the greater the amount produced.

(4) That only a part of the carbon of the core is converted into graphite. This not being increased, even by repeated use of the same grains, in successive carborundum furnaces.

The graphite formed by the destruction of carborundum, is remarkable in that it retains the form of the crystal of carborundum from which it is derived. It has, however, less than one-third the weight of carborundum and possesses the characteristic metallic gray color of natural graphite, but in size and form it so closely resembles the original crystal as to be, in fact, its pseudomorph in graphite. The graphite formed in the core is usually not so well defined, or distinct, as in that from carborundum, most of it being disseminated through the body of the individual grains in which it is found, the amount contained in any one grain varying with the percentage of impurity originally present. In some instances, the entire mass of the grain is converted into beautiful graphite, this occurring, I think, in cases where the grain is largely composed of slate, and it sometimes happens that one-half of the grain is completely converted, while the remainder is changed but little.

These two seemingly distinct methods of producing graphite from carborundum and from coke, are, in fact, identically the same; the first step in each is the formation of a carbide, the second its destruction. In making carborundum, silica and coke are mixed in the correct proportions to produce a true carbide, when heated in the electric furnace, without an excess of either constituent. In making

this mixture, account is taken of the impurities contained in the coke, and the silica reduced proportionately. In the case of the core, there is a natural mixture that produces a carbide from a portion of the carbon. The carbides formed under both of these conditions decompose when heated to a certain temperature above that at which they were formed.

This method of manufacturing graphite, I would define, as consisting in heating carbon, in association with one or more oxides, to a temperature sufficiently high to cause a chemical reaction between the constituents, and then continuing the heating until the combined carbon separates, in the free state. It is not, however, limited to the use of oxides, as pure metals, their sulphides and other salts may be used; but for various reasons the oxides are to be preferred.

THEORY OF FORMATION.

All of the methods of manufacture, thus far known, contain the same underlying, fundamental principle. Each of the six methods described by Muir, as well as my own method, contain as a part of the process, the expulsion or liberation of the carbon from a chemical association with one or more elements, and this occurs under conditions unfavorable to, or absolutely prohibitive of, its reassociation with the same or other elements. It is cast out, free to take unto itself such physical or other properties, as we must assume, properly belong to it in the free state, when formed under normal conditions. It has been shown by Moissan, that when subjected to great pressure, at the moment of separation from cast iron, carbon has those distinctive characteristics that cause it to be called diamond, while Scheele showed, in 1778, that the same carbon, separating from the iron without pressure, takes the graphitic form. Amorphous carbon, the third allotropic form, never occurs pure and is invariably produced from carbon held in chemical association with other elements, under conditions favorable to free chemical action between it and other elements.

The production of graphite by Rose's method—heating a diamond bedded in charcoal to the melting-point of cast iron—is a beautiful illustration of the return of a body

under strain, to the form it takes under normal conditions. It will be noted that the diamond was heated to the temperature at which it is known to form, as shown by Moissan's experiments; also that it was fairly well protected from chemical action.

The statement in the Encyclopædia Britannica that both diamond and amorphous carbon are converted into graphite, when heated by a powerful electric current, is very commonly held, indeed, I might say universally, although Berthelot concluded, from his investigations, that heat alone is without influence on carbon: that is to say, graphite is not changed to amorphous carbon, nor the amorphous to graphite, when heated to whiteness in an atmosphere of hydrogen or chlorine. That diamond will change to graphite, when protected from chemical influences, under the influences of high temperature, is undoubtedly true, and, indeed, is what might be expected from other known facts; but that *pure* amorphous carbon will change to graphite as the simple result of heating, is not proven, and certainly it does not occur at, or below, the temperature necessary for the transformation of the carbon in a carbide, to graphite.

From the facts in hand, I have deduced the following theory:

(1) Graphite is the form carbon assumes, when freed from chemical associations, under conditions of low pressure and protection from chemical influence.

(2) Diamond is the form carbon assumes, when freed from chemical associations, under conditions of high pressure and protection from chemical influence. And, by inference,

(3) Amorphous carbon is the form carbon assumes, when freed from chemical associations, under conditions of low or high pressure and exposure to chemical influence.

This theory does not, however, account for all of the observed facts, and must be supplemented by the hypothesis that catalysis occurs, under certain conditions, during the transformation of amorphous into graphitic carbon. The amount of graphite produced in the core of a carborundum furnace, and also in graphite articles I have made, is much

too great to be accounted for by the theory that it is formed by the dissolution of the fixed carbides, formed by the contained impurities and carbon sufficient to satisfy the chemical formula. The most probable and satisfactory explanation is that a catalytic action occurs—a progressive formation and dissolution of carbides. The temperature being much above the point of volatilization of silica, and all other possible impurities, a rapid dissipation of the active agents takes place and is completed, in this case, before the conversion of all of the amorphous carbon can occur.

COMMERCIAL MANUFACTURE.

As the result of my investigations and deductions, I think the only commercial way to make graphite is by breaking up a carbide by the action of heat. The carbon should be freed from chemical combination by what might be termed the evaporation of its associated elementary substances. I have secured patents covering this method, and these have been made the basis for the organization of an incorporated company, bearing the name "Acheson Graphite Company." The company has now under way the erection of works at Niagara Falls, where the necessary electric current will be obtained from the Niagara Falls Power Company.

Several distinct forms of the product will be produced. One consists of forms or articles, made out of amorphous carbon, with the desired amount of impurity added thereto, which will afterwards be heated in an electric furnace and converted, more or less, into graphite. I have been carrying on this line of manufacture for a year or more, using the furnaces of the Carborundum Company to produce the graphitization, the articles having first been made by the arc-light carbon manufacturers. Over 200,000 carbon electrodes, measuring 15 inches in length, with about 1 inch cross-sectional area, were made for use in the Castner alkali process, nearly one-half of them having been shipped to Europe, to be used for this work in England and Germany. The life or efficiency of these graphitized electrodes is many times that of the same electrodes ungraphitized. I have

also graphitized some tons of carbon plates, to be used in making dynamo and motor brushes, and a large variety of odd forms and sizes for divers purposes.

Another product—the one which will probably be of greatest importance—is an intimate mixture of pure amorphous carbon and graphite in fine powder. This will be put on the market for paint and foundry facing, and, as it has been formed at an extremely high temperature, it is quite pure, and possesses all of the qualities desirable for the purposes for which it is intended.

It is not the present intention of the company to enter into the manufacture of their product into finished form for the general market, but rather to encourage those who are now engaged in making up the natural graphite into articles of commerce to become buyers of their material, substituting it for that now used.

The company's plans, now being carried out, provide for the erection of a brick-and-iron building, 100 x 50 feet, on a plot of ground in Block No. 8 of the Niagara Falls Power Company's lands (adjoining the works of the Carborundum Company). Therein they will erect machinery for reducing coke to grains of the desired size, an electric furnace through which the prepared grains will pass in a continuous stream, a pulverizer for reducing the grains as received from the furnace, and a scalping sieve through which the product from the pulverizer will pass, that particles exceeding the $\frac{1}{200}$ of an inch diameter may be removed. The final flour or powder will contain an amount of pure graphite proportionate to the percentage of impurities in the original coke. It is quite possible that, instead of using high-grade, marketable coke, the fine refuse from the coke ovens, which is at present a waste material, will be utilized in the manufacture of this product.

In this connection I would call attention to the need of a specific name for the new product. *Artificial*, as applied to a product, chemically and physically identical with that made by Nature, is not pleasing; it conveys the impression that, failing to produce the real thing, a cheap imitation, a sham, is being palmed off as the genuine article. Not even

the Century Dictionary's definition of artificial, as "made or contrived by art, or by human skill and labor; opposed to Nature," is sufficient to banish this feeling; for, after all, in the particular case in hand, being ignorant of the exact methods pursued by Nature, we may be simply forcing her to reveal her methods, to the final results of which we neither add nor subtract one jot or tittle. The same objections may be made to the expression *artificial manufacture* of Graphite, for we may not be sure that the process forced upon her is not identical with that of her own selection. *Manufactured graphite* would be quite appropriate, were it not for the fact that it is popularly applied to articles made of graphite.

It may not detract from the general interest in this subject to call attention, in closing, to the fact that graphite, first shown to be an elementary body, an allotropic form of carbon, in the first year of the nineteenth century, is in this, the last year, made to order in great quantities, and that it will, before the close of the century, become an article of ordinary commerce in its new form. Perhaps it will take its place as the primitive form of carbon—the one it assumes under normal conditions.

NOTES AND COMMENTS.

ARTIFICIAL ALBUMIN.

In the London *Chemical News*, Mr. Alfred H. Allen questions the accuracy of the published reports respecting the artificial production of a laboratory product identical with albumin, which was credited to Dr. Leo Lilienfeld at the recent International Congress of Applied Chemistry at Vienna.

This announcement was received with unusual interest, because of the possible incalculable value of a practicable method of forming in the laboratory this product which is the fundamental constituent of all nitrogenous (or flesh-forming) foods.

Mr. Allen comments on the subject in the following terms:

"From the accounts which have hitherto come to hand, it appears that it is not true albumin of which Dr. Lilienfeld claims to have effected the synthesis, but 'peptone,' which is a very different thing. It is said to be produced by the condensation of glycocine (amido-acetic acid) with phenol, by means of phosphorus oxychloride. The reaction is said to occur quantita-

tively and with great facility, allowing of the whole process being shown at the meeting. Further, Dr. Lilienfeld is said to have demonstrated, by the most conclusive tests, the absolute identity of his product with natural peptone, or—according to some accounts—with true albumin. Seeing how very ill-defined are the chemical tests for 'peptone,' and that more than one kind of peptone is recognized, this part of the account must be received with caution. Still more doubt attaches to the statement that Dr. Lilienfeld's product has the same elementary composition as natural peptone (or albumin). Seeing that natural albumin and peptone both contain sulphur as an essential constituent, and that Dr. Lilienfeld's process does not involve the employment of sulphur in any form, there seems to be a screw very loose somewhere.

"Although the description of the mode of formation of Lilienfeld's body appears to negative the conclusion that he has effected the synthesis of either albumin or peptone, it by no means follows that he has not produced an albuminoid substance of great theoretical interest." W.

DOES IT PAY TO BUILD LARGE TELESCOPES?

Prof. George E. Hale, a noted American astronomer, answers this question by summarizing the principal advantages of a large telescopic object glass—40 inches aperture in the special case as compared with a smaller one of 10 inches.

These advantages consist:

(1) In the fact that the larger glass is capable of giving much brighter star images, and thus of rendering visible faint stars that cannot be seen with the smaller glass.

(2) In the fact that it gives at its focus an image of the object enlarged in proportion to its greater diameter.

(3) In its capacity to render visible, as separate objects, the components of very close double stars or minute markings on the surface of a planet or satellite.

The principal disadvantage of the large glass is that it demands better atmospheric conditions to bring out its best qualities.

He adduces several important astronomical discoveries which have been made possible only with the aid of large glasses, viz.: the discoveries of the fifth satellite of Jupiter and of the two satellites of Mars. Furthermore, the author declares that much fine detail which he has never been able to see with the smaller glass, is "clearly and beautifully visible" with the 40-inch glass. Also, he states, micrometrical measurements are effected with much more ease and certainty with the large instrument.

"It is particularly in astrophysical research that a great telescope is advantageous. It is necessary in spectroscopic observation to have as much light as can be gathered into a single point, and for this a large glass is essential. It follows from this that great telescopes have a mission to perform. While, on the one hand, they do not possess the almost miraculous gifts which imaginative persons would place to their credit, they do possess properties which render them much superior to smaller instruments and well worth all the expenditure which their construction has involved." W.

ELECTRIC CANAL-TOWAGE IN GERMANY.

The *Elektrotechnische Zeitschrift* conveys the information that the firm of Siemens & Halske is at present engaged in constructing an experimental electrical outfit for a trial of the method on a section of one of the German canals.

The plant consists of a power station from which current is supplied through an overhead conductor to electric locomotives, which run upon a narrow-gauge railway laid along the canal bank. The canal boats, in this case, will simply be towed—a number in each tow—by the engine.

In experiments on electric canal-haulage made in this country several years ago on the Erie Canal, it was proposed to run an overhead conductor along the canal line, and to equip the boats with electric motors, taking current for actuating their propellers from the line by the usual form of trolley. This, it will be observed, is subtantially different from the German plan above described. W.

INTERESTING MINERAL DISCOVERIES.

The following important notices of recent mineral discoveries were presented at the recent meeting of the American Association in Boston:

One of these is the discovery, near San Diego, Cal., of an enormous vein of lepidolite (lithia mica). This vein, where it has the best exposure, has a width of 60 feet. It is being utilized as a source of lithium. It is worked as an open quarry, and it is estimated that no less than 1,500,000 tons of mineral are available.

Another no less interesting item is the discovery of a new deposit of celestite—strontium sulphate—at Put-in-Bay, O. Large deposits of this mineral, which have been mined in this region for years, lately became exhausted, when by accident a large cavity was broken into while digging a well on Put-in-Bay Island. The walls of this cavity, which is described to be substantially a huge geode, were found to be lined with celestite. W.

SULPHURIC ACID AS A BY-PRODUCT.

The *Engineering and Mining Journal* is authority for the following interesting technical item:

"A new and interesting development in the chemical industry of the United States is the utilization of the sulphuretted hydrogen gas developed as a by-product in the refining of asphaltum at the California Asphaltum Company's Works at Ventura, Cal. The gas is burned to sulphurous anhydride in the usual well-known manner and the product of the combustion is conveyed to the lead chambers. Owing to the method of its production the gas is of a high degree of purity, and the acid produced is also of high grade. At present the output amounts to 10 tons per day, when the works are run at their full capacity.

"The Pacific Coast is beginning to have an important chemical industry. Sulphuric acid is made on a rather large scale at one other plant, while the manufacture of bluestone and boracic acid, carbonic acid, epsom salts, magnesia and numerous other products is now carried on. The State of California

has great natural resources upon which to base an important chemical industry, and its geographical position gives it an advantage in supplying certain markets of the Pacific Slope, so it is probable that a more important and interesting chemical industry will grow up there when the transportation problem is settled." W.

UTILIZATION OF SOLAR HEAT FOR POWER.

Prof. L. G. Carpenter, Fort Collins, Col., presented at the late meeting of the American Association in Boston the results of some interesting observations, continued during ten years, of the amount of solar energy received on our Western plains.

These observations show an intensity of from 7 to 17 calories per square meter, from 8 A.M. on sunny days. This is equivalent to from ½ to 1¼ horse-power per square yard. It appears also to be as reliable as the wind, which is exclusively used as a source of power for small plants. W.

NEW METHOD OF TESTING THE EFFICIENCY OF STEAM-PIPE COVERINGS.

A new method of testing the efficiency of coverings for steam pipes was described by Prof. Charles L. Morton before Section D of the American Association, which should be capable of yielding more accurate results than those in common use.

By this method a section of the steam pipe is heated electrically by means of a coil of wire in oil within the pipe. The amount of energy necessary to keep the pipe at a definite temperature is measured. Since the energy thus supplied is just sufficient to maintain a constant temperature, it must therefore equal the energy lost by the pipe. Hence, from the electrical energy supplied, the author is enabled to calculate the heat lost from the outside of the pipe.

As there is considerable discrepancy between the reported tests of the efficiency of a number of these materials in common use, the suggestion of this new method, which promises to yield more accurate results, is worth the attention of steam users. W.

THE SAND BLAST FOR CLEANING MASONRY.

The value of the sand blast for cleaning old and discolored masonry walls appears to be still open to question, but as all the facts bearing on the use of this mechanical agent for the purpose will be useful to the architect and builder, the latest reported example of the kind is herewith recorded on the authority of the *Iron Age*, viz.:

"The sand blast has been applied to the work of cleaning the stone walls of Pardee Hall, Lafayette College. The interior of the building was destroyed by fire some time ago, and after the standing walls had been pronounced safe for rebuilding, this method of removing the smoke-stains and crumbled surface was selected. The compressor was one of the Ingersoll-Sergeant direct-acting type, having a 10 x 10 inch steam cylinder and a 10 x 14½ air cylinder.

Ward & Nash sand blast apparatus was used. From the air receiver the air was carried by a pipe to the third floor of the building and from thence by a hose to the portable sand blast apparatus. The velocity given to the sand was quite high, and the bombardment of the particles cut away the discolored surface in a very rapid and satisfactory manner. The pointing between the stones was cut away, but that had nearly all been cracked by the fire and would have had to be done over again in any case. The sandstone arches and facing around the windows were cut away very rapidly, and care had to be taken that the dressed edges were not spoiled."

A NEW PROCESS FOR CASE-HARDENING INGOTS.

The Demenge process of hardening steel ingots, which is in use at one of the principal steel works of France, consists in directly carburizing one of the faces of the ingot, at the time of casting, by lining one of the vertical sides of the mold with carburizing substances. The carburizing action is prevented from penetrating too deeply into the inside of the ingot by casting the vertical side opposite to the carburizing side. The carburization of the one face by this method is said to be quite uniform.

The case-hardened surface is rather rough; but all irregularity disappears in forging, which may be effected without special precaution and at a comparatively low temperature, by the press rather than the steam hammer. Ingots of ¼ to 3 tons have been cast in this manner; and a 3-ton ingot, 16 inches thick, reduced by forging and rolling to one-fourth that thickness, was found to contain from 1·78 to 1·5 per cent. of carbon between its hard surface and a depth of $\frac{3}{16}$ inch; from 0·60 to 0·40 per cent. between 1 and 2 inches from the surface, and from 0·35 to 0·15 per cent. between $3\frac{3}{16}$ and 4 inches.

This method appears to be capable of accomplishing substantially the same results as those attained by the so-called "Harveyizing," but more simply.

W.

APPLICATION OF WIRELESS TELEGRAPHY TO NAVIGATION.

Mr. W. J. Clarke, an American electrician, has suggested a means of detecting the presence of a ship or an iceberg by wireless telegraphy. The apparatus which he proposes is so arranged that when two ships approach each other a large vibrating gong will ring in each, and the transmitter is so arranged that the signal would be operated at a distance of from one to ten miles. Mr. Clarke claims that if it were made compulsory that sea-going vessels should be so equipped with the necessary outfit, it could be carried out at a small cost.

W.

IMPROVEMENT IN THE ART OF SEPARATING METALS ELECTRICALLY.

Tomassi, an Italian expert, has proposed a mechanical improvement in the operation of the electrolytic bath used for the extraction, separation and refining of metals, which may prove to be of practical value. The aim of the inventor is to reduce the resistance in the electrolytic cell, and thereby reduce the cost. His electrolyzer consists of a rectangular tank in which are placed

two anodes between which is placed a circular metallic disc mounted on a gun-metal spindle, and capable of being rotated. The disc is partly out and partly in the bath, and so comes in contact with the air and the electrolyte. The part of the disc outside the electrolyte comes in contact with two scrapers, one on each side, which scrape off the spongy deposit and depolarize the surface. The anodes are either in the form of plates, or in receptacles containing coarse powder. When the cathode has a sufficiently thick layer of metal it is taken to a bath of molten metal similar to that deposited, and the electrolytic deposit is melted in the bath, and then the cathode is taken back to the electrolyzer. Mr. Tommasi claims that polarization is entirely done away with, that the metal deposited is removed as the deposition proceeds, and that the density of the liquids in all parts is the same. W.

MANGANESE STEEL FOR BURGLAR-PROOF SAFES.

The discovery of manganese steel is due to Mr. R. A. Hadfield, the present head of the famous Hecla Works, in Sheffield, England.

The discovery of a metal of such extraordinary properties, combining as it does the highest tensile strength with absolutely unapproached elongation, started steel metallurgists all over the world experimenting to see if they could discover some steel or alloy having even higher physical properties. This search has resulted in the discovery of some valuable steels, notably those produced through the addition of molybdenum and vanadium, but nothing equalling manganese steel in the combined properties of hardness and toughness has been produced.

It was long ago proposed that manganese steel would make a good burglar-proof safe, but as the material was too hard to be machined, no way was devised to apply it for the purpose.

This difficulty, it is stated, has at length been overcome. Experiments with guncotton and dynamite on manganese steel plates are said to have demonstrated that the resistance of this metal to the action of explosives is unequalled by that of any metal at present known. W.

AN ALUMINUM HAND-CAR.

An aluminum railroad hand-car is being built by the St. Louis Aluminum Casting Company, and the makers propose its adoption by railroad companies to take the place of the ordinary muscle-taxing contrivance used by track workers. The new car will be constructed largely of an aluminum alloy of great strength and lightness, that is, the wheels, body, and walking beam will be made of this metal. The axles will be of steel tubing. Other improvements will consist of gearing of the bicycle pattern, admitting of adjustments for speed, of ball bearings, and of a hub brake, whereby brake power may be applied by simply pressing a button. The new car will weigh not more than 150 pounds, or only about a third as much as the ordinary hand-car, and one man can lift it off or on the track. It is believed that two men can easily run it from thirty to thirty-five miles an hour for a limited time. W.

ELECTRIC RIVETING MACHINE.

Before the Institution of Naval Architects of Great Britain, at one of its recent meetings, there was presented a description and an account of the performance of an electric riveting machine, which has been successfully applied to ship-building purposes. The machine is portable, and can be carried to any part of the yard. After thoroughly testing its capabilities, the inventor claims that it can be advantageously substituted for the two most advanced types of such machines now in use, namely, the hydraulic and pneumatic machines. The capacity of the electric machine is 120 rivets per hour, and it can close rivets up to 1¾ inches in diameter. The machine described at the meeting above named is said to have been steadily at work for months, closing 1,200 rivets per day of ten hours, with the attendance of only three men and a boy.

W.

HIGH EXPLOSIVES AND SMOKELESS POWDERS.

Mr. Hudson Maxim, a well-known authority in the field of modern high explosives, presented some highly impressive data on the subject before the Chemical Section of the Franklin Institute, at one of its recent meetings. The gist of his discourse was the strong advocacy of much more destructive projectiles than are now used in warfare. This will appear in the following abstract:

He dealt with the history and development of smokeless powders, with particular reference to the well-known Maxim-Schœpphaus progressive burning smokeless powder for cannon, which is an American invention, and which has been adopted in the United States Army and Navy.

"While this powder possesses many characteristics of originality and value in its chemical composition," he said, "its distinguishing feature is its character of combustion. This is known as progressive burning. The grains of the powder are made somewhat larger than the usual cannon powder, and are multi-perforated—that is, pierced with a large number of small holes. This shape of grain enables the presentation of a smaller initial combustion area in the gun than do other forms of powder grains. The combustion starting with a small area confined to the perforations, becomes more rapid as the holes become larger, presenting an increase of burning area. It is a modified form of this same powder which is proposed for throwing high explosives from ordnance. The torpedo powder is made with a view to presenting the minimum of area of the initial flame with consequent minimum of initial pressure.

"The present 12-inch United States seacoast rifle weighs about 52 tons, and will throw a projectile, consisting of 963 pounds of steel and a bursting charge of only 37 pounds of black rifle powder. The pressure used in the gun is about 35,000 pounds to the square inch, and with the usual forms of powder grains this pressure falls off rapidly, and the average pressure in the gun is about 22,000 pounds. This causes a velocity of the projectile, under the best conditions, of about 2,250 feet per second.

"With a torpedo gun weighing the same as the present 12-inch gun, costing the same, and being of the same length and of the same outside dimensions for the rear half of its length, but having a caliber of 24 inches, a half

ton of high explosives may be thrown at the same velocity as by the 37 pounds of black powder. The basis for the reasoning is as follows:

"With a pressure of only 12,000 pounds at the breech, and 10,000 at the muzzle in the torpedo gun, an average pressure would be had of 11,000 pounds to the square inch, just one-half the average pressure in the 12-inch gun; but in the torpedo gun the pressure is exerted for the same length of travel of shot over four times the area of base of projectile; consequently from the torpedo gun the projectile would be thrown with twice the muzzle average, and hence a projectile of twice the weight may be thrown without sacrifice of velocity. In other words, a projectile may be thrown weighing 1 ton, consisting of ½ ton of steel and ½ ton of high explosive, with the same velocity and accuracy as the present 12-inch shell is thrown.

"The character of high explosive that will be thrown will be wholly insensitive to the shock of acceleration in the gun of such explosives as picric acid or wet guncotton.

"By making a torpedo shell consisting of 1 ton of steel and filled with ½ ton of picric acid, the deck armor of any battleship in the world could be penetrated by one of these shells thrown from a seacoast battery, and explode inside the vessel, or the same would pierce the belt armor of a protected cruiser like the "New York," and explode inside. The velocity of even this shell would be upward of 2,000 feet per second.

"I propose simply to throw larger quantities than are now thrown, without subjecting the gun to any more shock. Naval and military authorities must give attention to the aërial torpedo. The first shock from a torpedo gun to throw the missile I have described will render obsolete every battleship in the world. Then needless sums of money will not be expended on armor protection which does not protect. The American fleet expended $2,000,000 worth of ammunition on Santiago hills, and the damage done was probably not more than 10 per cent. of that sum.

"The war taught nothing concerning the value of the torpedo boat. The great lesson taught is the superiority of the American gunners and fighters. War is occasionally a necessary contingency, and when it comes we want the best tools to fight with." W.

THE OLDEST KNOWN ROCK.

Among the numerous interesting papers presented at the recent meeting of the American Association for the Advancement of Science was one by Prof. N. H. Winchell, State Geologist of Minnesota, in which he described the so-called greenstones of that State, and advanced certain arguments in support of the view that these rocks were the oldest known rocks in the world. He considers them to be the bottom rocks of the geological series and the representative of the original crust of the earth formed from the molten mass by the earliest solidification.

The so-called Laurentian rocks of Canada have hitherto been considered by geologists to represent the oldest rocks, but Professor Winchell advances proofs to show that the greenstones of Minnesota are older. W.

CAUSE OF THE GLACIAL PERIOD.

Mr. Warren Upham, at the Boston meeting of the American Association, presented some important data on this subject. He stated that the results of recent investigations showed that the cause of the glacial climate was the considerable continental elevation which occurred in immediately antecedent time, and that the amount of this elevation was much greater than was supposed. He stated further that the elevation for the northern half of North America amounted to from 3,000 to 5,000 feet above the present level. W.

LEAD *vs.* ZINC PAINTS.

G. R. Henderson, of the Norfolk & Western Railroad, contributes to the *Railroad Gazette* a report of a series of exposure tests to determine the efficiency of lead and zinc paints. For the different materials he reaches the following results:

Tin.—The best results were obtained with first coat white lead and second coat white zinc. The second coating of zinc gave generally the best results, and the second coating of lead the worst.

Galvanized Iron.—The same remarks apply to galvanized iron that were given for tin.

Sheet Iron.—The mixture of one-third white zinc and two-thirds white lead, for both coats, gave the best results on this material, and in general the zinc paint gave better results than the lead paints.

Poplar.—The second coats of zinc showed up well on poplar, no matter whether the priming coats were white lead or white zinc, or mixed lead and zinc. The lead second coating showed up the worst on this material, but in each case where the second coat was of zinc, totally or partially, the paint was in a perfect condition.

White Pine.—The remarks made relating to poplar apply to white pine also.

Yellow Pine.—This material seems to be difficult to properly treat with paints; the best results were obtained with the first coat of lead, and the second coat of lead and zinc mixed. Where the first coat was of lead and zinc mixed, or entirely of zinc, the results were poor throughout, which seems to indicate that as a general thing the lead is better for priming on this material.

Conclusion.—The lead priming and zinc coating are generally good for tin, galvanized iron, poplar and white pine. Sheet iron showed up best with both coats of mixed paints. Yellow pine appeared best with the first coat of lead and the second coat of lead and zinc mixed. Comparing the materials which were painted, we find that generally poplar retains the paint better than white pine, and would, therefore, be preferred for siding on buildings, etc. Yellow pine seems to be the worst of all for this purpose. Black iron, as a whole, seems to retain the paint better than either tin or galvanized iron. W.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, May 17, 1899.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 17, 1899.

MR. JOHN BIRKINBINE, President, in the chair.

Present, 102 members and visitors.

Additions to membership since last monthly report, 43.

The President gave a brief outline of the plans being made by the Board for the appropriate celebration of the seventy-fifth anniversary of the Institute. These comprise a series of special anniversary meetings by the several Sections, to follow each other on successive evenings; the celebration to be concluded by a special meeting of the Institute, at which addresses will be delivered by distinguished invited guests and members of the Institute. It is proposed that the ceremonies above-outlined should occupy one entire week during the month of October, and that they should take place in one of the buildings of the Exposition to be held in the autumn.

The Secretary, at the suggestion of the President, gave a brief account of the joint meeting of the Chemical and Mining and Metallurgical Sections and the Lehigh Valley Branch of the American Chemical Society at Bethlehem, Pa., which took place on Tuesday, May 16th. (For an account of this meeting see the proceedings of the Sections.)

Mr. N. Monroe Hopkins, Washington, D. C., described and illustrated "The Pneumatic System for Preventing the Bursting of Water Pipes by Freezing." This method, invented by the speaker, consists, in brief, in introducing along the line of pipe to be protected, at intervals of say every 10 feet, where the pipe is exposed to the danger of freezing, a series of small globular air-chambers, to provide sufficient space for the increased volume of the water in solidifying. To insure the continuous maintenance of the air in these chambers, an automatically operating inspirator is introduced in the main service pipe, which, whenever a faucet is opened, causes the introduction of a small quantity of air, which finds its way to the chambers, thus insuring that they shall always be kept supplied.

The subject was discussed by Messrs. J. C. Trautwine and Spencer Fullerton and Mr. Hopkins.

The invention was referred to the Committee on Science and the Arts for investigation and report.

Mr. Wm. McDevitt, Inspector of the Philadelphia Board of Fire Underwriters, gave an account of his investigation of the recent explosion, which occurred at the chemical works of Frank H. Fleer & Co., No. 2343-45 Callowhill Street, this city. The investigation disclosed that the cause of the explosion was the priming of the contents of a large tank containing some 70 gallons of benzole used as a solvent in the final operation of manufacturing artificial vanillin.

The subject was discussed by Dr. Goldschmidt, Mr. Fullerton and others.

Several views by Mr. W. N. Jennings, showing the progress being made on the Exposition buildings, were shown, and described by the President. Mr. Jennings also exhibited a remarkable lightning photograph taken by him.

Adjourned. WM. H. WAHL, *Secretary.*

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held Wednesday, May 3, 1899.*]

PROF. EDGAR MARBURG in the chair.

The following reports were considered:

Plastic Rail-bond for Electric Railways.—Thomas A. Edison and Harold P. Brown, New York.

Acid-blast Method and Apparatus for Etching Metal Plates.—Louis Edward Levy, Philadelphia.

Improvement in Internally-fired Water-tube Boilers.—Robert D. Kinney, Philadelphia.

The foregoing reports were passed on first reading and laid over under the rules for final consideration at the next stated meeting.

The following reports were passed finally:

Chimneys for Incandescent Lamps.—Ernest M. White, Philadelphia. A protest against the Committee's report was filed by applicant. Considered by the Sub-Committee. The Sub-Committee decided to reaffirm its report, and recommended that the protest be dismissed. Approved.

Improvement in Pipe-joints.—Clinton A. Higbee, Philadelphia.

ABSTRACT.—The Higbee pipe-joint consists of a taper thread, the section of same being of the truncated V variety, but the ridge of the throat is truncated to a greater extent than the base, so that a space will be left on the ridge of both the male and the female thread when the joint is made. It is claimed that a flow of metal will take place when the thread is forced up, which will have the effect of filling the remaining space, producing a better joint than it is possible to obtain with the standard V-threaded pipe-joint.

The invention is the subject of letters-patent of the United States to Clinton A. Higbee, No. 597,000, January 11, 1898, to which reference is made for additional details.

The Sub-Committee charged with the investigation of the merits of this invention decided to institute comparative tests of this joint with the standard joint without the use of any paste, such as plumbers use for closing the minute leaks due to imperfections of the joint. As the result of three separate tests of this nature, the conclusion is reached: (1) That neither the Higbee joint nor the standard joint is likely to give satisfaction without the use of some paste; and (2) that there is no material difference between the Higbee and the standard pipe-joint. [*Sub-Committee.*—Hugo Bilgram, Chairman; L. L. Cheny, J. Logan Fitts.]

Contribution to the Physics of Thermo-Chemistry.—Gustave Westman, Jersey City, N. J.

The Sub-Committee finds that while the thesis is intelligible, it is improb-

able *a priori*; also, that the proof submitted is entirely inadequate. [*Sub-Committee.*—Jos. W. Richards, A. W. Goodspeed, Livingston Morgan, Hugo Bilgram, Geo. F. Stradling.]

Railway Tie.—Edward L. Brown, Calverton, Suffolk County, N. Y.

ABSTRACT.—This invention is the subject of letters-patent of the United States to Edward L. Brown. (Allowed July 6, 1898.)

It consists of a metallic tie for railways, composed of two duplicate parts, which, when brought together, will form a complete tie and rail clamp.

Each of this pair of members consists of a horizontal or base flange, and a vertical flange. The latter is cut away where it engages the rail flange in such manner as to form a hook, which is designed to embrace the outer flange of one rail, while on the opposite end a portion of the metal is turned aside, leaving a similar hook to embrace the inside flange of the opposite rail. The combination of these parts in duplicate, forms what is claimed to be a widened support for the rail. When in position, embracing the rail as above described, the two members constituting the tie—which are duplicates of each other in reversed position—are bolted together or otherwise secured in place. The report finds the invention to be open to several serious objections. [*Sub-Committee.*—H. F. Colvin, Chairman; D. R. Mehaffy, Jacob J. McConnell.]

SECTIONS.

(*Abstract of Proceedings.*)

CHEMICAL, MINING AND METALLURGICAL SECTION.—*Joint Meeting* in conjunction with the Lehigh Valley Branch of the American Chemical Society at Bethlehem, Pa., held Tuesday, May 16th.

Forty-five members and friends attended the meeting. A special car for the accommodation of the party was provided by the Passenger Department of the Philadelphia & Reading Railway Company.

The visiting members were received in Bethlehem by Dr. Joseph W. Richards, President of the Chemical Section, and a representative of the Bethlehem Steel Company. The itinerary of the meeting embraced a visit to and inspection of the Government Ordnance Plant at the Bethlehem Steel Company and the various buildings of the Lehigh University. After this inspection the visitors enjoyed a luncheon furnished by the local committee and adjourned to the Lecture Room of the Chemical Department of the University, where the formal proceedings of the meeting were held. Dr. Joseph W. Richards, presided.

The following communications were presented:

"On the Use of Iron in the Purification of Water and Sewage." Dr. T. M. Drown.

"The Theodolite Goniometer and Gnomonic Crystal Projection." Dr. J. W. Richards.

"The Manufacture of Graphite in the Electric Furnace." (Exhibition of specimens.) Dr. William H. Wahl.

"Historical Sketch of the Liquefaction of Gases." Dr. H. F. Keller.

"A New Volumetric Method for Magnesia." Mr. R. K. Meade.

At the close of the meeting, Mr. James Christie, president of the Mining and Metallurgical Section, made a brief address, expressing on behalf of the visiting members their appreciation of the courtesies received at the hands of the Local Committee of the Lehigh Valley Branch of the American Chemical Society.

MECHANICAL AND ENGINEERING SECTION.—*Postponed Meeting*, Tuesday, May 18th, 8 P.M., Mr. Wilfred Lewis, president, in the chair. The subject for discussion was "Hydraulic Transmission, Valves and Packing," and was opened by Mr. Jefferies, of Camden, N. J.

PHYSICAL AND ASTRONOMICAL SECTION.—The inaugural meeting of this Section was held this evening in the Lecture Hall of the Institute in the presence of a large number of interested participants.

The President of the Institute opened the proceedings with a brief congratulatory address. The Secretary of the Institute gave a brief account of the events leading up to the formation of the Section, whereupon, on motion, Dr. E. A. Kennelly was chosen chairman *pro tem.* and Dr. Wahl, secretary *pro tem.*

The inaugural address was then delivered by Prof. Cleveland Abbe, of Washington, D. C., his theme being "The Relation of Physics and Astronomy to the Development of the Mechanic Arts." Also, addresses apropos to the occasion were made by Prof. T. C. Mendenhall, president of the Worcester Polytechnic Institute, Worcester, Mass.; Prof. A. S. Mackenzie, of Bryn Mawr College, Pa.; Dr. A. E. Kennelly, Prof. George F. Stradling, Central Manual Training School, Philadelphia; Professor Luigi D'Auria, Philadelphia, and others.

Profs. George A. Hoadley, E. A. Partridge and George F. Stradling were appointed a special committee to suggest nominations for permanent officers, and to take such other measures as might be found necessary to perfect the organization of the Section.

The meeting passed a unanimous vote of thanks to Professors Abbe and Mendenhall, the invited guests of the Section, for their valued contributions to the proceedings of the inaugural meeting.

(The communications above referred to will appear in the *Journal* in due course.) W.

ELECTRICAL SECTION.—*Stated Meeting*, Tuesday, May 23d, 8 P.M., Professor Hoadley, President, in the chair.

The proceedings embraced a lecture by Mr. James Hamblett, manager of the Telegraphic Time Service of the Western Union Telegraph Company, New York, on the subject of "Electrical Clocks, Historically Considered, with a Description of the most successful Applications of Electricity to Clocks and the Uniform Distribution of Time."

Mr. Hamblett illustrated his remarks by the exhibition of models and lantern slides.

Mr. J. D. Darling described and exhibited a new form of primary battery, known as the "Harrison Cell," for which special merits were claimed.

(The foregoing communication will appear in the *Journal*.) W.